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VARIABLE VENTRICULAR COMPLEXES IN HEART BLOCK, AND THEIR RELATION TO BILATERAL BUNDLE BRANCH BLOCK

BY

C. W. CURTIS BAIN

From the Cardiographic Department, Harrogate General Hospital

Received November 29, 1940

Variable ventricular complexes in heart block have been recorded by a number of writers since they were first described by Mathewson (1913). King (1934) found them in five out of thirty-six cases with the double lesion of complete heart block and bundle branch block. Cohn (1913) noted both left and right bundle branch block and transitional complexes in a case passing from partial to complete A-V block, and he suggested that the changes might be due either to depression of conductivity in both branches alternately or else to a wandering pacemaker. Gilchrist and Cohn (1928) thought the latter explanation the more likely, and attributed the transitional complexes to the almost synchronous discharge of impulses from centres in each ventricle. Similar views have been expressed by Willius (1924), by Coelho (1932), and by Scherf and Schott (1932). On the other hand, Mathewson considered that in his case the impulse was being conducted alternately by each branch.

The diagnosis of bilateral bundle branch block was first made by Cohn and Lewis (1912) in a patient who had suffered from many Stokes-Adams attacks and was found at autopsy to have both branches divided from each other and from the main stem; the QRS was widened to ·2 sec., which they thought might be characteristic of the condition. Faulkner (1932) also gives bilateral bundle block as an explanation of a wide QRS without axis deviation. However, in a similar case of separation of the branches from each other and from the main stem reported by Don, Grant, and Camp (1932) variable ventricular complexes occurred without gross widening of the QRS and they attributed the changes to a shift in the pacemaker from one ventricle to the other.

The suggestion that lesions are more likely to be found in the bundle branches than in the main stem, when variable ventricular complexes accompany A-V block derives from the experimental work of Wilson and Hermann (1921). When both branches of the bundle had been cut in dogs, they found that standstill of the ventricles only lasted a few minutes, after which centres in each ventricle took over. The resulting complexes might be of either branch block

type or might be normal. Transitional complexes they ascribed to the interplay of two centres, one on each side of the heart, which were not discharging their impulses synchronously. When one branch started to recover, incomplete A-V block occurred for a time combined with bundle branch block that was permanent. Interest in this conception of bilateral bundle branch block was revived by Yater, Cornell, and Clayton (1936), who made histological studies in three cases of heart block with varying ventricular complexes; in one they found that both branches were destroyed, while in the other two there was extensive disease in each of the branches ; in all three the main stem was relatively healthy: they concluded that in all cases of heart block associated with variable ventricular complexes the pacemakers are situated in the ventricles below lesions in the branches, and that the leadership of the pacemaker changes from one side to the other.

Four such cases have been recently observed. Two were usually associated with complete A-V block ; in two the A-V block varied. When dealing with ventricular centres a difficulty arises, since a rhythm originating in a bundle branch is designated by a term that indicates disease in the other branch, which may not be present. To avoid confusion, the classical terminology of bundle branch block adopted by the Criteria Committee of the New York Heart Association (1939) has been followed in describing the cases, except that a QRS of ·12 sec. has been deemed sufficiently long to justify a diagnosis of bundle branch block. But in the discussion curves will usually be described according to the branch through which conduction takes place.

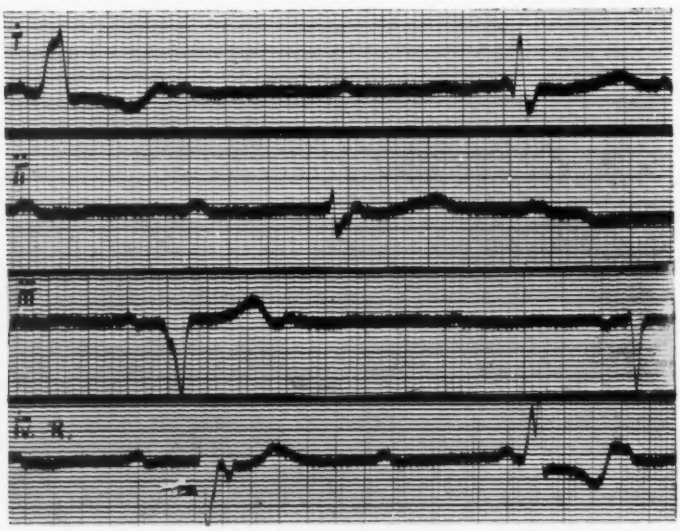


FIG. 1.—Case 1. 14,7,39. Complete A-V block with a ventricular rate of 26. Alternate left (discordant type, QRS ·15 sec.) and right (type B, QRS ·12 sec.) branch block. Note inverted P deforming S–T interval in first complex of lead IVR. (See p. 78.)

NOTES OF THE FIRST CASE

A man of 67 had noticed dyspnœa on exertion for two months. His pulse rate was 32. A musical systolic murmur was audible at the apex, and a harsh systolic murmur at the aortic base. The heart was a little enlarged to the left; the ascending aorta was prominent; the blood pressure was 190/110; and the Wasserman reaction was negative. He was taken into hospital in July 1939

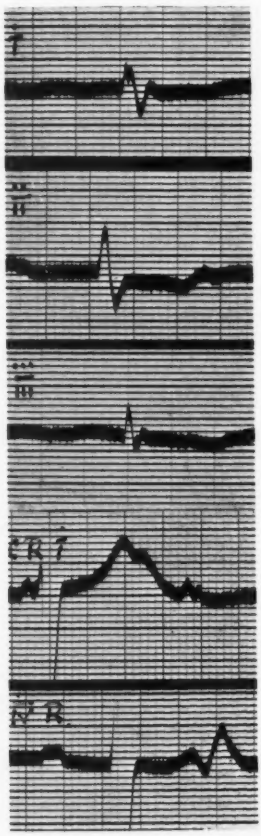


FIG. 2.—Case 1. 25,7,39. Complete A-V block. Low voltage curve of right-sided type (QRS ·11 sec.).

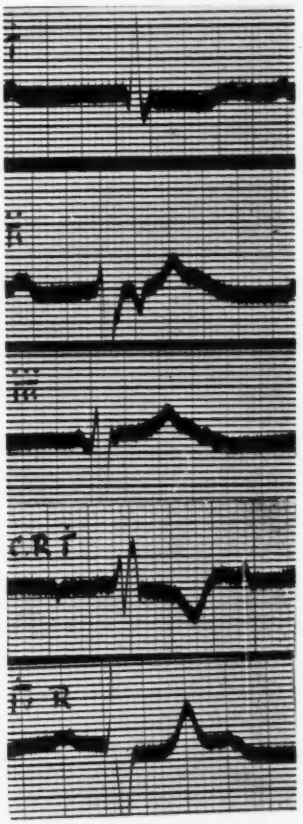


FIG. 3.—Case 1. 1,8,39. Complete A-V block. Right branch block (type B, QRS ·12 sec.). Note inverted P deforming S–T interval in lead II.

for observation. Ephedrine had no effect upon the ventricular rate, and he now maintains fair health upon moderate doses of digitalis. He has never had Stokes-Adams attacks.

Numerous electrocardiograms taken during his stay in hospital and since his discharge all showed complete A-V block. The P waves were not very

regular and were sometimes flattened. On six occasions early inverted P waves deformed the S–T period, indicating retrograde conduction from ventricle to auricle. They all followed the R wave by ·16 to ·18 sec., and occurred when the interval between the preceding P and the R was from ·50 to ·58 sec. (Figs. 1 and 3).

The ventricular complexes varied. Fig. 1 shows complexes of left and right branch block. The left branch block complexes are of the discordant type and they have a QRS of ·15 sec. The right branch block complexes are of type B and have a QRS of ·12 sec. The ventricular rate is 26 and regular. No transitional complexes are present.

After rest the left branch block complexes disappeared, and their place was taken by a low voltage curve of right-sided type with a QRS of ·11 sec. at a rate of about 30 (Fig. 2), which has alternated with the right branch block (Fig. 3) since.

Injection of ·5 c.c. adrenaline at a time when the low voltage curve was present led to an acceleration of eight beats (from 30 to 38). No premature beats were seen, but the following changes were observed: After three minutes the curve returned to right branch block, type B; after eight minutes two complexes, with a normal QRS of ·07 sec., occurred (Fig. 4): at ten minutes

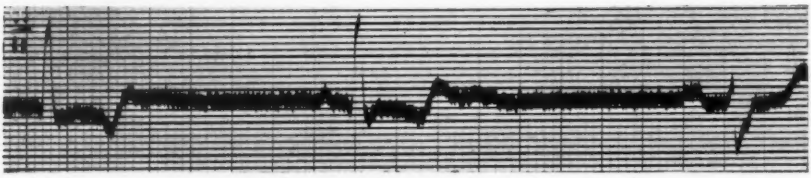


FIG. 4.—Case 1. 25,7,39. Showing two complexes with QRS of ·07 sec., 8 minutes after injection of ·5 c.c. of adrenaline.

the low voltage complexes were again present, but from thirteen minutes onward the curve returned to right branch block, type B.

Summary.—In a man with complete heart block in the forward direction but with evidence of retrograde conduction at times from ventricle to auricle, the following changes in the ventricular complexes were observed.

1. Left bundle branch block (QRS, ·15).
2. Right bundle branch block of type B (QRS, ·12).
3. Low voltage curve of right sided type (QRS, ·11).
4. Normal QRS (·07) after adrenaline.

NOTES OF THE SECOND CASE

A man of 67 was admitted to the Harrogate General Hospital in June 1939. He had been conscious of dyspnœa on exertion since an attack of influenza two months previously. He had experienced three attacks of unconsciousness during the previous two days.

The pulse rate was 32. There were no murmurs, but auricular sounds

were audible at the apex. The heart was considerably enlarged to left and right, the cardio-thoracic ratio being 16 cm./28 cm. The blood pressure was 200/70. The Wasserman reaction was negative.

He was allowed to get up, but he then complained of dizziness, and the pulse rate was found to have fallen to 26. He was given ephedrine, gr. ii daily, and the pulse rate subsequently fluctuated from 32 to 36. He was discharged in fair health, but later Stokes-Adams attacks recurred and he died in one in May 1940.

Most of the electrocardiograms showed complete A-V block ; incomplete (2: 1) A-V block occurring only at the end of, and for a short time after, his stay in hospital. On six occasions, when complete A-V block was present, early inverted P waves deformed the S–T period, indicating retrograde conduction from ventricle to auricle. They all followed the R wave by ·16 sec., and occurred when the interval between the preceding P and the R was from ·42 to ·50 sec. (Figs. 5, 6, and 13).

Fig. 5, taken on admission, shows complete A-V block at a rate of 37 and

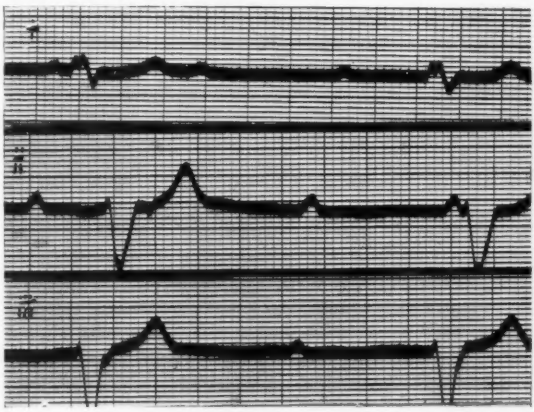


FIG. 5.

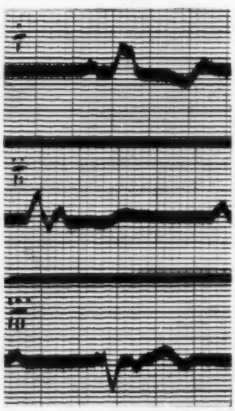


FIG. 6.

FIG. 5.—Case 2. 16,6,39. Complete A-V block. A typical right branch block (QRS, ·14 sec.). Inverted P wave deforms S–T interval of first complex in lead II.

FIG. 6.—Case 2. 22,6,39. Complete A-V block. Left branch block (QRS, ·12 sec.). Inverted P wave deforms S–T interval in lead III.

a bundle branch block with a QRS of ·14 sec., which, though somewhat atypical, has been interpreted as a right branch block in view of the form of the chest leads recorded later (see Fig. 17). Fig. 6, which was taken after the fall in rate had been noted, shows a left branch block of the discordant type, (QRS, ·12) at a rate of 29. For the next week the left branch block persisted, with rates varying from 27 to 32. Adrenaline ·5 c.c. was then given subcutaneously. This had no effect upon the ventricular rate, but after seven minutes a right branch block complex appeared, and after eleven minutes the curve changed to a type A right branch block (QRS, ·14) at a rate of 27 in lead I and of 33 in lead III (Fig. 7).

Three days later the A-V heart block began to lift, and the left branch block complexes now followed P waves with a P–R interval of ·24 sec. At the same time right branch block complexes returned, being still associated with complete A-V block (see Fig. 17 on p. 84). Four days later incomplete (2: 1) A-V block became established, both with left (Fig. 8) and right (Fig. 9, leads II and

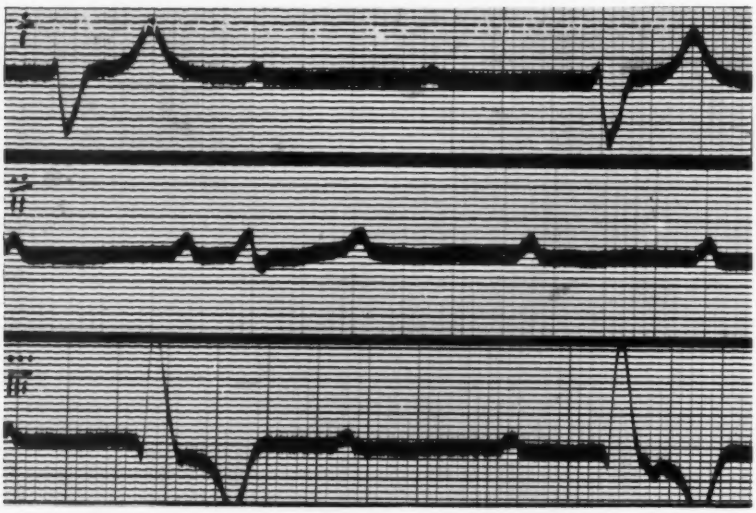


FIG. 7.—Case 2. 28,6,39. Eleven minutes after injection of ·5 c.c. adrenaline. Complete A-V block (V. rate 27 in lead I and 33 in lead III). Right branch block (type A, QRS ·14 sec.).

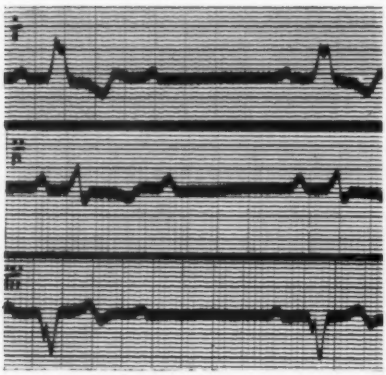


FIG. 8.

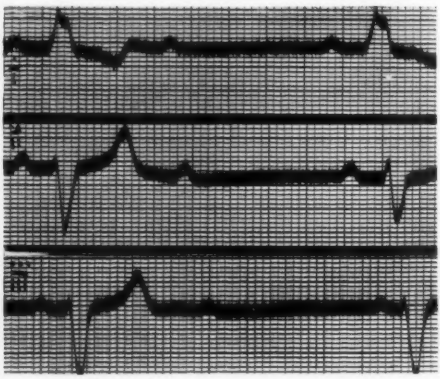


FIG. 9.

FIG. 8.—Case 2. 6,7,39. Incomplete (2 : 1) A-V block and left branch block (QRS, ·14 sec.).

FIG. 9.—Case 2. 6,7,39. Incomplete (2 : 1) A-V block with left branch block in lead I and right branch block in leads II and III. There is some variability in the QRS of the complexes in lead II, and of the P–R intervals in lead III.

III) branch block, though there is some variability in the P–R intervals of the right branch block complexes. Incomplete (2:1) A-V block (with left branch block) persisted for two months, and lead II in Fig. 10 contains a run of three beats of 1:1 rhythm, the middle beat being a right branch block complex.

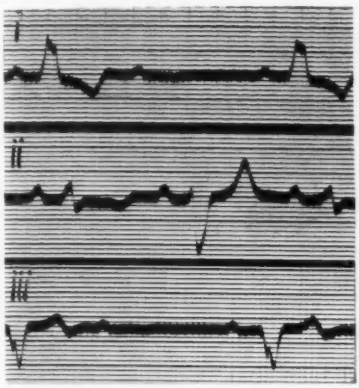


FIG. 10.

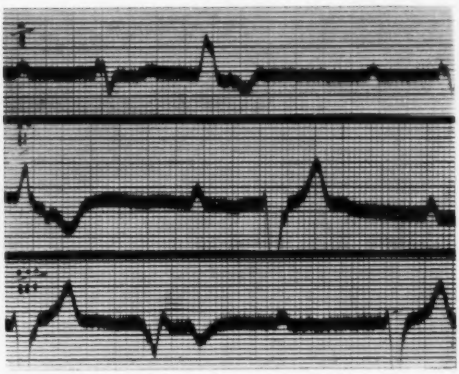


FIG 11.

FIG. 10.—Case 2. 28,7,39. Left branch block with incomplete (2:1) A-V block. In lead II a run of three beats of 1:1 rhythm occurs, the middle complex being one of right branch block.

FIG. 11.—Case 2. 22,9,39. Complete A-V block. Right branch block. Right ventricular premature contractions. An inverted P deforms the S–T period in the premature beat in lead II.

In September 1939 complete A-V block returned with right branch block, and early beats were seen arising from the right ventricle somewhat dissimilar in form from the left branch block complexes previously observed (Fig. 11). An inverted P deforms the S–T period in the early beat in lead II and again in Fig. 13. Later, a transition from left to right branch block was recorded (Fig. 12), and a change from right to left branch block was obtained ten minutes

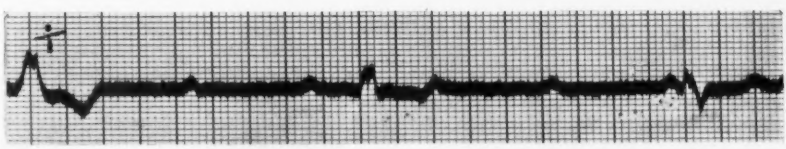


FIG. 12.—Case 2. 13,10,39. Complete A-V block. Transition from left to right branch block.

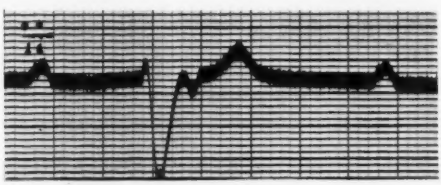


FIG. 13.—Case 2. 19,2,40. Lead II. Complete A-V block. Right branch block. An early and inverted P deforms the S–T period.

after the subcutaneous injection of atropine, gr. 1/30, associated on this occasion with an increase in the rate from 31 to 35.

Summary.—A man who died from Stokes-Adams disease had A-V heart block, usually complete in the forward direction, but with evidence of retrograde conduction at times from ventricle to auricle. The following changes in the ventricular complexes were observed.

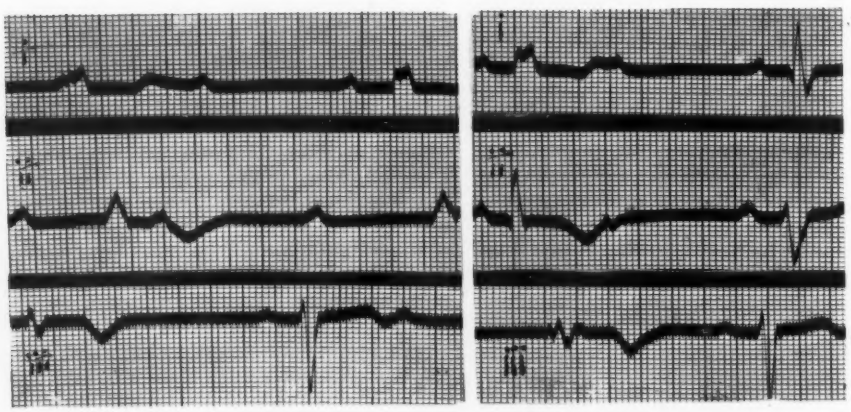
1. Right branch block, atypical (QRS, ·14).
2. Left branch block (QRS, ·12–·14).
3. Right branch block of type A (QRS, ·14) after adrenaline.

Notes of the Third Case

A man of 59 was seen with Dr. Kerr Pringle in October 1937. In 1935 he had developed pernicious anæmia but the blood had been restored to normal. Three weeks previously he noticed a fullness in his neck and became conscious of the beating of his heart, the rate of which was found to be 30. Since then he had been kept in bed.

The heart was not enlarged. There were no murmurs. The blood pressure was 160/110. Cardiograms showed a mixture of complete and incomplete (2:1) A-V block. He was admitted to hospital next day, when it was found that incomplete (2:1) A-V block only was present. Normal rhythm was restored, both by atropine and adrenaline, and was maintained during his stay in hospital with ephedrine. Subsequently he reverted to 2:1 A-V block, but a spontaneous return to normal rhythm took place seven months later and was maintained for a year. In July 1939 complete A-V block returned with a pulse rate of 20. Ten days later he experienced a succession of Stokes-Adams attacks, in one of which he died.

Fig. 14 shows that complete A-V block was associated with left branch block



A B

Fig. 14.—Case 3. 19,10,37. (A) and (B) Left branch block (concordant type, QRS ·14 sec.) associated with complete A-V block at a rate of 30. Also right branch block (type B. QRS ·15 sec.) associated with incomplete A-V block (P–R ·28 sec.). The first complex in lead II in (B) is transitional and has a QRS of ·10 sec.

of the concordant type (QRS, ·14) at a rate of 30, while right branch block, type B complexes (QRS, ·15) followed P waves with a P–R interval of ·28 sec. Their rate (from 33 to 44) is faster than that of the left branch block. In Fig. 14B the first complex in lead II (QRS, ·10, sec.) is transitional. On the following day atropine, gr. 1/30, was given subcutaneously, and Fig. 15

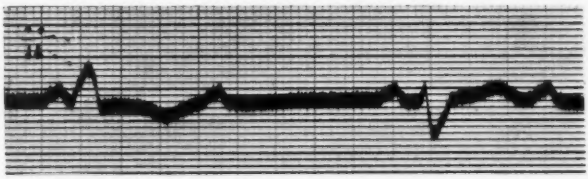


FIG. 15.—Case 3. 21,10,37. After injection of atropine, gr. 1/30. An early beat arises in the right ventricle 5 minutes before restoration of normal rhythm.

shows an early beat from the right ventricle which occurred five minutes before the restoration of normal rhythm. Next day adrenaline (1 c.c.) restored normal rhythm in five minutes, but subsequently induced premature beats from both ventricles (Fig. 16). Six months later, and a fortnight before the spontaneous

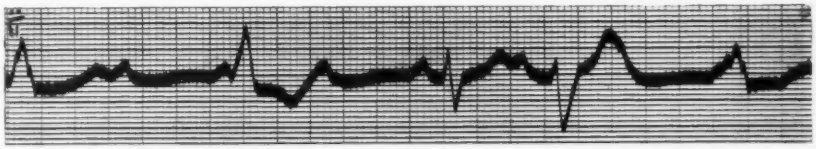


FIG. 16.—Case 3. 22,10,37. Premature beats from both ventricles after injection of 1 c.c. of adrenaline.

resumption of normal rhythm, early beats from the right ventricle occurred again (Fig. 18 on p. 84) and a transitional complex is seen at the end of lead III.

On July 9, 1939, he noticed his heart was acting slowly and his pulse rate was found to be 20. On July 18 he had six Stokes-Adams attacks. When seen on July 19 the pulse was 20, but the apex rate was faster, since there were beats which were not being transmitted to the wrist. While being attached to the cardiograph he had a Stokes-Adams attack. When the apex impulse returned, the rate was 50 and irregular. Fig. 19, taken a few minutes later, shows a return to the left branch block (concordant type) at a regular rate of 44. The QRS is still ·14 sec., but T is now flat in lead II and upright in lead III. The complexes resemble the premature beats from the right ventricle induced by adrenaline rather than the idio-ventricular rhythm of the first record, or the early beats that occurred spontaneously. The Q–T interval is prolonged to ·72 sec., compared with ·60 sec. during the initial phase and ·44 sec. when normal rhythm was present.

Summary.—In a man who died from Stokes-Adams disease complete A-V block was associated with left branch block of the concordant type (QRS of ·14), while incomplete (2: 1) A-V block and normal (1: 1) rhythm were associated

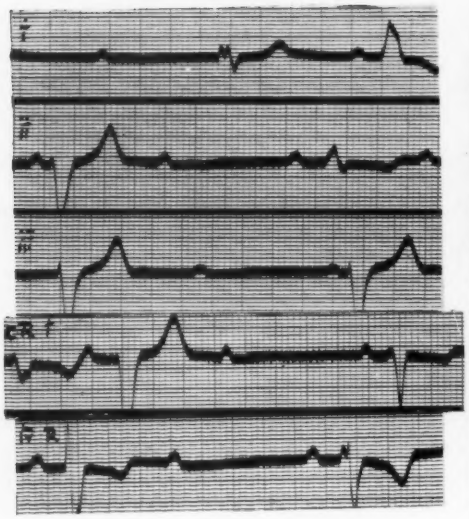


FIG. 17.

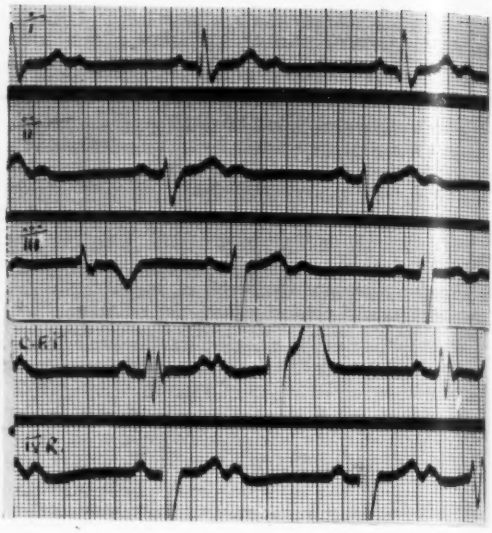


FIG. 18.

FIG. 17.—Case 2. 1,7,39. Alternating right and left branch block in leads I, II, CRI, and IVR. In lead III both complexes are right branch block. The third complex in CRI is transitional. Right branch block is associated with complete A-V block. Left branch block complexes follow P waves with a P–R interval of ·24 sec.

FIG. 18.—Case 3. 22,5,38. Incomplete (2 : 1) A-V block. Right branch block (type B). Early beats from right ventricle similar to the left branch block complexes of first record seen in leads III and CFI and IVR. The last complex in lead III is transitional.

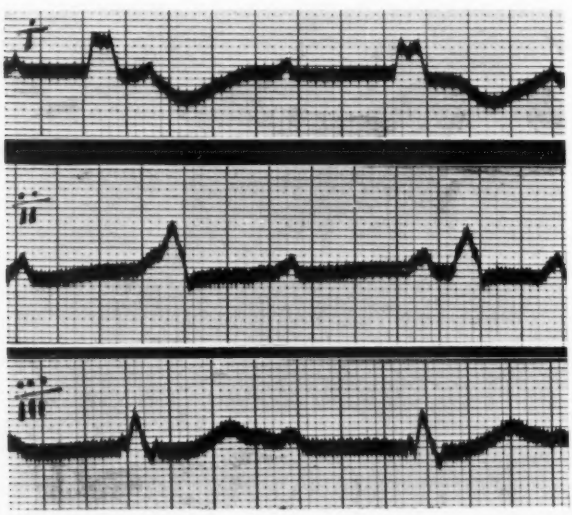


FIG. 19.—Case 3. 19,7,39. Left branch block (concordant type, QRS ·14 sec.). T_2 flat. T_3 upright. Q–T interval is ·72 sec.

with right branch block of type B (QRS, ·15). A transitional complex with a QRS of ·10 sec. was observed.

Notes of the Fourth Case

A man, aged 64, was admitted to the Harrogate General Hospital in September 1936 with a history of increasing dyspnœa on exertion for two years and œdema for ten weeks. Four years previously his gall-bladder had been removed for severe and gripping pains in the upper abdomen. A partial iridectomy for glaucoma was performed in the same year.

He was cyanosed and orthopnœic with œdema in the legs, scrotum, and lumbo-sacral region. The pulse was 96. The blood pressure was 156/110. The heart sounds were faint, with an apical gallop rhythm. The heart was greatly enlarged to the left and right, the cardio-thoracic ratio being 19 cm./33 cm. A tender liver was palpable eight inches below the costal margin. The lungs were congested. The cardiogram showed incomplete A-V block (P–R, ·24 sec.), atypical right branch block (QRS, ·12) with small deflections in lead I, and right ventricular premature beats (Fig. 20). Under digitalis therapy the heart failure disappeared and he was discharged in three weeks.

In November the blood pressure was 120/68. Fig. 21 shows incomplete

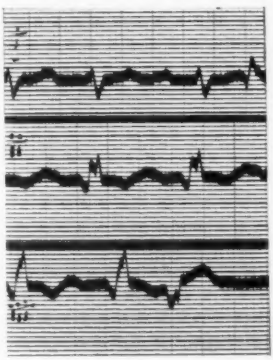


Fig. 20.

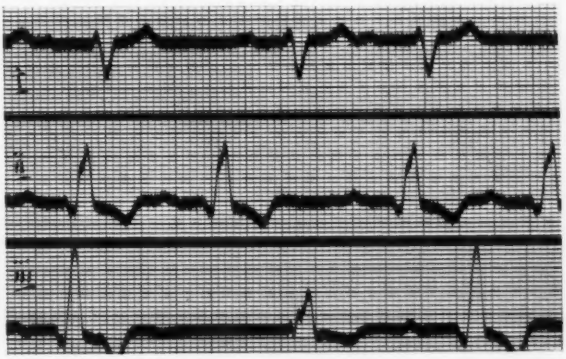


Fig. 21.

Fig. 20.—Case 4. 21,9,36. Incomplete A-V block, (P–R ·24 sec.). Right branch block (atypical; QRS, ·12 sec.). Right ventricular premature beats.

Fig. 21.—Case 4. 6,11,36. Incomplete A-V block (P–R, ·24 sec.). Coupled rhythm probably due to premature auricular beats. Right branch block (type A; QRS, ·14 sec.). In lead III the second complex is an escape of the ventricle following the failure of an auricular beat. It has a form similar to the atypical right branch block of previous record.

A-V block (P–R ·24 sec.); coupled rhythm probably due to premature auricular beats; right branch block of type A (QRS ·14); and a ventricular rate of 68. In lead III an auricular beat fails, and the escaping ventricular complex returns to the atypical right branch block. In January 1937 auricular fibrillation was present (Fig. 22), with a ventricular rate of 42 to 60. The right branch block (type A) is unchanged, and in lead II another atypical right branch block

complex is seen after a long pause. In June 1937 complexes of left branch block (QRS, ·12) appeared in leads I and III, interspersed with the predominant right branch block of type A (Fig. 23). They resembled the premature beats of Fig. 20. By November 1937 the ventricular rate was regular at 40, auricular fibrillation persisting. The QRS of the right branch block had increased to ·16 sec. (Fig. 24).

One morning in June 1938 he had several attacks of unconsciousness and he was admitted to hospital at noon. The pulse was then 36. From 1 p.m. to 2 p.m. he had eleven Stokes-Adams attacks, for which adrenaline was given. From 5.30 to 6 he had five more and at 11 he died in another. Fig. 25 was taken at

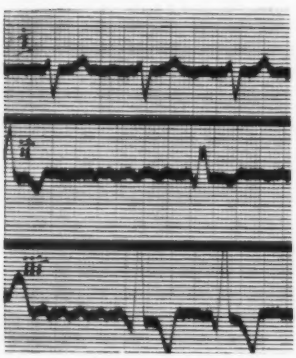


FIG. 22.

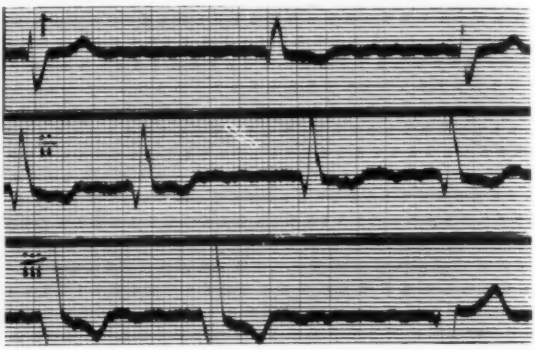


FIG. 23.

FIG. 22.—Case 4. 12,1,37. Auricular fibrillation. Right branch block, type A. The second complex in lead II reverts to the atypical right branch block of Fig. 20.

FIG. 23.—Case 4. 1,6,37. Auricular fibrillation. Right branch block, type A. Left branch block seen in leads I and III, similar to the early beats of Fig. 20.

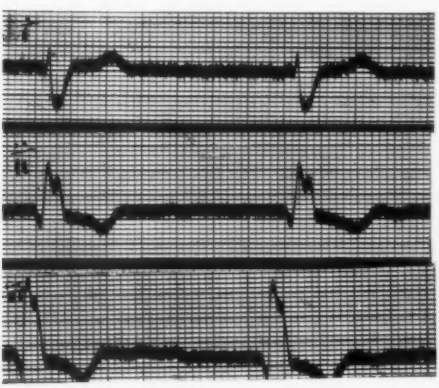


FIG. 24.

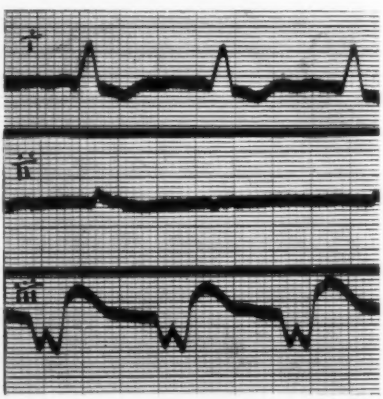


FIG. 25.

FIG. 24.—Case 4. 14,11,37. Auricular fibrillation and complete A-V block (ventricular rate 40 and regular). Right branch block (QRS, ·16 sec.).

FIG. 25.—Case 4. 6,6,38. Left branch block at regular rate of 90. (QRS, ·18 sec.).

1·45, lead II being exposed during a period of unconsciousness. Leads I and III show a left branch block with a regular rhythm at a rate of 90, the QRS being ·18 sec.

Summary.—In a man with congestive heart failure, who died from Stokes-Adams disease, the following changes in the ventricular complexes were observed:

1. Right branch block, atypical (QRS, ·12) with incomplete A-V block (P–R, ·24 sec.).

2. Right branch block of type A (QRS, ·14–·16) with incomplete A-V block and later auricular fibrillation. Atypical right branch block complexes occurred when the ventricle escaped after the failure of an auricular contraction, and after longer pauses when the auricles were fibrillating.

3. Left branch block complexes (QRS, ·12), occurring interspersed with predominant right branch block of type A, and resembling the right ventricular premature beats seen in the first record.

4. Left branch block (QRS, ·18) at a regular rate of 90.

Discussion

Before considering the relation of these curves to bilateral bundle branch block and the evidence in favour of centres in each ventricle as against alternate conduction down each branch it will be advantageous to review the position regarding the width of the QRS.

Duration of the QRS.—Lewis (1925) held that a QRS duration exceeding ·10 sec. was sufficient for the diagnosis of bundle branch block, and this view has been adopted by Hunter, Papp, and Parkinson (1940). With an average normal QRS duration of ·08 sec. this allows ·03 sec. for the impulse to cross the septum. On the other hand, the *Criteria Committee of the New York Heart Association* regard ·13 sec. as the minimum figure for a diagnosis of bundle branch block, which agrees with the statement of Ashman and Hull (1937) that it takes ·05 or ·06 sec. for the impulse to cross the septum. It has sometimes been assumed that bundle branch block is synonymous with obstruction to the passage of the impulse, but this is not so. As Comeau, Hamilton, and White (1938) state: " So long as the conduction time through the damaged branch is greater than that through the intact branch plus the myocardial pathway between the two ventricles, . . . bundle branch complexes will result." It follows that the duration of the QRS will be in part a measure of the conducting powers of the relatively healthy branch. In bilateral disease with bundle branch complexes the accepted minimum must always be exceeded. Bilateral bundle disease appears to be common: Yater (1938) found some disease in each branch in all of the six cases of bundle branch block that he examined. Moreover, the QRS values in his cases confirm the importance of conduction in the

relatively healthy branch. Out of three cases of right branch block, two had a QRS of ·12 sec.: in each the right branch was destroyed, but in one the left branch was " almost normal," while in the other it was " not interrupted." The third case had a QRS of ·16 sec., and here the right branch was destroyed and the left branch was " almost destroyed." In the three cases of left branch block neither branch was destroyed, so the correlation was less good. Evidence that the impulse may need only ·03 or ·04 sec. to cross a septum that is not unduly thick is contained in the study made by Master, Dack, and Jaffe (1938) of bundle branch lesions following coronary occlusions. In two cases (Nos. 4 and 15) a branch block changed after successive occlusions and the QRS increased by ·03 or ·04 sec. on each occasion. In one a QRS of ·10 sec. became ·14 sec. with left branch block after the second attack, and increased to ·18 sec. with right branch block after the third. In all the cases here recorded the QRS width of some of the ventricular complexes exceeded ·13 sec., and it may be that QRS widths of this order signify bilateral conduction defects and that some curves with QRS widths from ·11 to ·13 sec. represent a purely unilateral defect. It has, in fact, been recently suggested that chronic bundle branch block usually results from diffuse changes in both branches and that the type of the block is determined by predominant enlargement of one or other ventricle (Master, Kalter, Dack, and Jaffe, 1940).

Bilateral Bundle Branch Block can be diagnosed with confidence when supra-ventricular impulses pass down each branch alternately, as in Case 2 (Fig. 10). When A-V block is complete the diagnosis is less certain, since it is possible for alternate right and left bundle branch block complexes to be due to the interplay of two ventricular centres, one above a lesion in a branch and the other below it. Thus Fig. 1 (Case 1) might be interpreted as being due to the activity of a centre about the point of division of the bundle, with conduction down the left branch alternating with impulses from a centre below a lesion in the right branch. But it is most unlikely that two ventricular centres would have exactly the same rate, and the characteristic of multiple ventricular centres is the appearance of transitional complexes. In Fig. 1 there are no transitional complexes and the R–R intervals are equal, the changes in the branch block complexes having no effect on the regularity of the rhythm. Moreover, the left branch block complexes with a QRS of ·15 sec. ceased after rest and the curve changed to a low voltage curve of right-sided type with a QRS of ·11 sec., and seven days later, following the injection of adrenaline, the QRS became normal. It would seem that in this patient conduction normally took place down the left branch (*R.B.B.B.*) activating the ventricle in ·12 sec., but in the early stages, by reason of fatigue, this route was not available for the alternate impulses which then passed along the more diseased right branch (*L.B.B.B.*) reaching the ventricle in ·15 sec. When conduction improved with rest the QRS fell to ·11 sec., and it was restored to normal by adrenaline. The factor of fatigue is also important in Fig. 10, which records the only run of normal rhythm obtained from Case 2, since the first complex shows conduction down the right branch (*L.B.B.B.*), the second down the left branch (*R.B.B.B.*) and the third again down the right.

The curves of Case 3 conform to the experimental records of Wilson and Hermann: who found that, when one branch started to recover after both had been cut, incomplete heart block might occur for a time combined with bundle branch block that was permanent. When first seen complete heart block was starting to lift three weeks after an abrupt onset. The ventricle was being activated from a centre in the right branch (*Complete Heart Block* and *L.B.B.B.*), but some supraventricular impulses were coming through at a faster rate with conduction through the left branch (*R.B.B.B.*) (Fig. 14). One complex showed almost normal conduction, due to the simultaneous activation of both ventricles by the two routes. As recovery proceeded incomplete heart block became established, and then normal rhythm, at first under the influence of atropine, adrenaline, and ephedrine, and later spontaneously; but right bundle branch block persisted. The centre in the right branch produced early beats immediately before normal rhythm was restored by atropine and shortly before it returned spontaneously. The rhythm during the final phase of complete heart block with Stokes-Adams attacks was furnished by a second centre which was probably lower down in the right branch since the complexes resembled the premature beats induced by adrenaline.

In Case 4 incomplete heart block (P–R, ·24 sec.) was present in the early records. Later the auricles fibrillated, but it is probable that complete dissociation was present when the ventricular rate became regular at 40 (Fig. 24). Conduction through the ventricle was down the left branch (*R.B.B.B.*) with a gradual increase in the QRS from ·12 to ·16 sec.; but a centre in the right branch was responsible first for early beats (Fig. 20) and later for escapes of the ventricle following longer pauses during auricular fibrillation (Fig. 23). All these complexes had the same form and a QRS of ·12 sec. The final curve (Fig. 25) shows conduction through the right branch, or from a centre in it, at a rate of 90 with a QRS of ·18 sec. In a similar case, Comeau, Hamilton, and White (1938) attributed the new rhythm to irritation of an impulse-forming centre in the diseased branch; but in their case the QRS decreased from ·16 to ·14 sec. with the change in the branch block instead of increasing as here from ·16 to ·18 sec. Moreover, the centre previously active in the right branch had hitherto shown a constant QRS of ·12 sec. It is possible that the quickened rate might be associated with a wider QRS, but it is much more likely that the gradual increase in the QRS of the right branch block complexes was due to increasing difficulty of conduction in the less damaged left branch, and that in the last phase fresh damage in that branch made it necessary for the impulse to travel through the right branch, which had hitherto provided the slower route.

Multiple Impulse-forming Centres in the Ventricle.—In Cases 1 and 2, A-V block was always complete, except for a short time in Case 2. Both, however, showed evidence of retrograde conduction from ventricle to auricle when the time relations with the preceding P waves were favourable, and the R–P interval was ·16 to ·18 sec. It cannot be supposed that an impulse generated below a lesion in a branch sufficiently dense to cause complete forward block could penetrate that lesion, traverse the main bundle, pass through the node and

activate the auricle in ·16 sec. The variable branch block complexes in these cases cannot, therefore, be explained by postulating ventricular centres below lesions in the branches. Moreover, in Case 2 the complexes did not alter during the phase of incomplete A-V block when the ventricles were responding to supraventricular impulses. However, in this patient conduction through the left branch (*R.B.B.B.*) changed after a spell of dizziness to conduction through the right branch (*L.B.B.B.*) at a slower rate, and the rate with conduction through the right branch was always rather slower during complete A-V block than with conduction through the left, except once after atropine. Many transitional complexes were also observed. Most of these were minor alterations in shape affecting chiefly the right branch block complexes (Fig. 9, lead II), but an intermediate complex is seen in Fig. 12 which shows transition from left to right branch block. The evidence suggests that two ventricular centres were active, while complete A-V block was present, but that both were above the lesions in the branches. In Case 3 transitional complexes, one with an almost normal QRS, point to a ventricular centre in the right branch in addition to the supra-ventricular impulses which passed along the left branch; and another centre in the right branch was responsible for the rhythm during the last phase. Case 4, too, had a second impulse-forming centre in the right ventricle which produced premature beats, and later, escapes of the ventricle. These three patients all died from Stokes-Adams disease.

In Case 1 there was no evidence of a second ventricular centre. No transitional complexes were seen, no variations in speed between the right and left branch block complexes, and no premature beats. It is difficult to avoid the conclusion that in this case a single centre above the point of division of the bundle was responsible for all the complexes observed with variable conduction down each branch. This patient had no Stokes-Adams attacks.

Curves of Incomplete Bundle Branch Block.—The increase in the QRS of the right branch block complexes in Case 4 was associated with a change in their form. The early curves with a QRS of ·12 sec. had small deflections, especially in lead I; the later curves were of the classical type A right branch block. There can be little doubt that the first type represent a less complete form of right branch block, since they reappeared as escapes of the ventricle on those occasions when the conducting tissue had more time in which to recover owing to the failure of an auricular contraction (Fig. 21). The right branch block curves of Case 2 (QRS, ·14) similarly had small deflections in lead I, and they changed to right branch block of type A after adrenaline. The fibre was under continuous observation from the time of the injection and no cessation of ventricular activity was seen. The rate of the type A complexes in lead I was 27, which is less than the rate before injection. The complexes appeared to be due rather to a change in the path of the impulse than to the activity of a new centre.

It has been suggested that curves with a QRS width between ·10 and ·12 sec. should be interpreted as incomplete bundle branch block, but with bilateral disease the width of the QRS can bear only a limited relationship to the completeness of the bundle branch block. Lewis (1925) was of the opinion that

delay in conduction down one branch could modify considerably the form of the cardiogram, and it is probable that some of the atypical forms recently interpreted as right branch block may in reality signify incomplete bundle branch block, the widened QRS being due to bilateral disease.

Summary and Conclusions

Four cases of A-V heart block with varying ventricular complexes have been observed. In two the A-V block was nearly always complete, although retrograde conduction occurred at times from ventricle to auricle; in the other two the A-V block varied. Analysis of the curves obtained suggests that bilateral bundle conduction defects were present in all of these cases. In three the evidence pointed to multiple centres of impulse formation, and these all died from Stokes-Adams disease; in one it was concluded that variable conduction was taking place down each branch from a single idio-ventricular centre, and he has had no Stokes-Adams attacks.

1. Varying ventricular complexes in A-V heart block usually signify the presence of bilateral bundle conduction defects.

2. The impulses may arise from one or more places in the ventricles. Multiple foci of origin increase considerably the risk of Stokes-Adams attacks.

3. The duration of the QRS in bundle branch block is in part a measure of the speed of conduction in the relatively healthy branch: in bilateral bundle lesions the accepted minimum must always be exceeded. In those cases in which one branch is conducting normally, this minimum width may not exceed ·11 sec.

4. Some forms of atypical right branch block may represent incomplete right branch block, the wide QRS being due to the presence of bilateral defects.

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HYDROTHORAX IN HEART FAILURE

BY

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The term " hydrothorax " was applied to clear, non-purulent, pleural effusions before percussion and auscultation were practised and before the signs of heart disease were known. The diagnosis then depended entirely on symptoms, and MacLean (1810) in an early treatise on hydrothorax wrote as follows: " when respiration is considerably impeded, especially on motion, in a horizontal posture, or on ascending an acclivity, when the countenance is at the same time pale and sallow, assumes a leaden or livid hue; the urine small in quantity, high coloured, and, on cooling, deposits a reddish or pink-coloured sediment; the pulse irregular or intermitting; the feet, ankles, or hands swell and are colder than natural; and the patient is suddenly roused from sleep by a sense of suffocation or extreme anxiety about the praecordia, attended with palpitation; the most superficial observer will have no doubt of the presence of a watery fluid in some of the cavities of the chest, and that the person thus affected labours under the disease termed hydrothorax, or dropsy of the chest."

Morgagni (1761) described the association of hydrothorax with heart disease post-mortem and thought that, of the two, the heart lesion was more likely to be the primary condition ; but it was Corvisart (1818) who first really distinguished between hydrothorax consecutive to heart failure and idiopathic or essential hydrothorax, i.e. pleurisy with effusion. He pointed out that cardiac hydrothorax was always associated with ascites and general anasarca Laennec (1826), though he gave an admirable and separate account of pleurisy with effusion, still recognized the two varieties of hydrothorax described by his teacher. Idiopathic hydrothorax was unilateral; symptomatic or secondary hydrothorax was bilateral and usually a terminal condition. He seems to have regarded the absence of adhesions and false membrane as the essential criterion of hydrothorax, though he admitted that the distinction from chronic pleurisy was often as difficult in the cadaver as during life, and mentioned inflammatory hydropsies as having been described. Comte (1822), in his treatise on hydrothorax, does not appear to have recognized heart disease as the cause, though signs of heart failure were often mentioned and digitalis was advocated in treatment. He regarded the palpitation and irregular pulse as due to pressure

on the heart and therefore as characteristic of left hydrothorax or hydropericardium.

The term "cardiac pleurisy," introduced by Bucquoy (1882) and Forgeot (1885), soon became current in France, and papers by Robert (1897), Barié (1902), Rénon (1905), Roubier and Thévenet (1906), Sergent (1925), and Joly (1935) may be mentioned as important in this connection.

A distinction was drawn between hydrothorax due simply to transudation and cardiac pleurisy regarded as an inflammatory exudate secondary to pulmonary infarction, sub-pleural hæmorrhage, congestion or acute œdema of the lung (Huchard), pericarditis, or perihepatitis. This distinction depended partly on clinical considerations and partly on the nature of the effused fluid, namely, its specific gravity, chemistry, and cytology. In general, a bilateral effusion was regarded as a transudate and a unilateral one as an exudate, though it was recognized that pleural obliteration might occasionally explain a unilateral transudate of the opposite side. Beaufumé (1907) established the occurrence of unilateral hydrothorax by describing sixteen cases, in all of which the aspirated fluid had the properties of a transudate. Later, Steele (1904), Joly (1935), and others found it impossible to separate the pleural effusions of heart failure into transudates and exudates, since the qualities of the fluid were often intermediate between these two, corresponding to a " mixed type " of effusion, and our experience confirms this view.

It is now generally stated that hydrothorax is either bilateral or right-sided, which teaching dates back to the last century (Wintrich, 1854) and receives a measure of support from statistics furnished by Steele (1896, 1904), Stengel (1901), Beaufumé (1907), Lickint (1928), Joly (1935), and others, based on clinical or post-mortem findings. Scherf (1936), reflecting the view of the Vienna school, states that hydrothorax is bilateral or right-sided except under certain specified conditions, namely, obliterative pleurisy on the right side, left pulmonary infarct, or pericardial effusion, when a left unilateral hydrothorax may occur.

Present Investigation

In the course of routine X-ray examination of patients with heart failure, and especially while investigating the lung stasis of left heart failure, we have encountered left unilateral hydrothorax in many cases where pulmonary infarction seemed excluded, and far more frequently than can be explained in terms of the views already mentioned. In the absence of any recent statistics based on radiological diagnosis, we have investigated the distribution of hydrothorax anew. In doing so, we have included all serous pleural effusions developing coincidentally with heart failure, for which no extracardiac cause was evident. Effusions associated with pulmonary infarction and heart failure have not been excluded because we believe they are essentially transudates.

The incidence and distribution of hydrothorax was analysed in 356 cases of congestive failure (including left heart failure) encountered at the Middlesex Hospital, the National Hospital for Diseases of the Heart, and in practice.

Radioscopy (or orthodiagram) was done as a routine in all out-patients and in those seen in the consulting room; radiography was carried out later in most cases.

An additional analysis has been made of the post-mortem findings in 109 consecutive cases dying from heart failure, from the records of the Bland-Sutton Institute of Pathology over a period of five years.

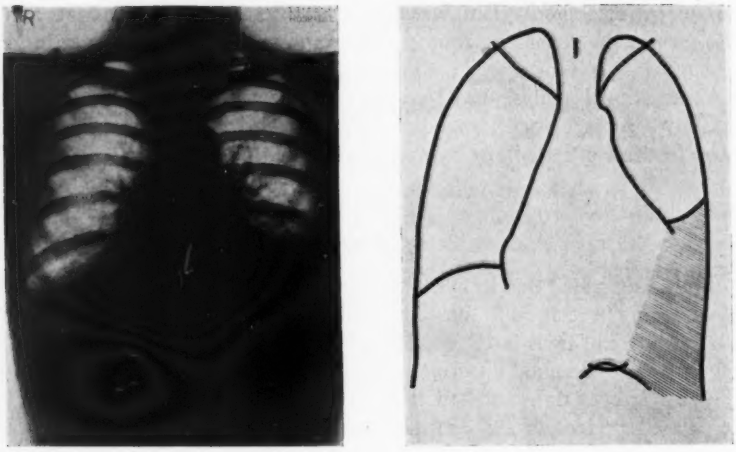
Diagnosis

It has been stated that in hydrothorax the clinical signs of fluid in the chest may be scanty in relation to the volume of the effusion. Certainly the interpretation of physical signs is complicated in heart failure by elevation of the diaphragm from abdominal distension. Swelling of the liver tends to exaggerate the higher level of dullness at the right lung base and may suggest fluid there when none is present, or may neutralize dullness due to a small left hydrothorax. Error in the opposite sense arises when basal dullness is wrongly attributed to pulmonary œdema which, as Laennec taught, is imperceptible to percussion. Basal râles due to pulmonary œdema usually persist with a small hydrothorax, and pleural friction is common apart from infarcts, especially when the fluid is being absorbed. Because of the difficulties mentioned, X-rays are essential for the sure detection of small effusions; but if clinical signs of fluid are methodically sought in every case of heart failure, even if œdema is absent, a hydrothorax of appreciable size need rarely be overlooked.

Even a small hydrothorax can be recognized with certainty by radioscopy, which is far superior to radiography in this respect. In screen examination the tube can readily be centred at the upper level of the effusion, and this, combined if necessary with rotation of the patient into the oblique position, usually permits a sharp fluid level to be visualized. In films, taken with the tube centrally placed, a small effusion is often ill-defined and difficult to distinguish from congested lung or thickened pleura. In a small or medium-sized hydrothorax the fluid is mobile and fluctuates freely with movements of the diaphragm, thus making easy its distinction from pleural adhesions or lung opacities. In left hydrothorax the diaphragm is often depressed, so that the size of the effusion will be underestimated unless the left dome of the diaphragm is rendered visible by inflating the stomach with gas, which may be done as a routine by giving alternate draughts of sodium bicarbonate and tartaric acid in solution (Figs. 1 & 2 on pp. 96 & 97).

Incidence of Hydrothorax

In 356 consecutive cases of heart failure, hydrothorax was observed at some stage or other in 136 (38·5 per cent). This series includes patients with failure when first seen and others who developed failure while under observation. The diagnosis of hydrothorax was established in 89 cases by X-ray examination, and in 20 of the remaining 47 cases the clinical diagnosis was confirmed by



a. *b.*

FIG. 1.—(*a*) Routine radiograph showing left hydrothorax. (*b*) Orthodiagram after inflation of stomach with gas, showing true size of effusion and depression of diaphragm. From a woman aged 45, with hypertension and left heart failure.

paracentesis or at necropsy. Stengel (1901) reported hydrothorax in 17 of 100 cases of heart failure, and Barié (1902) found " cardiac pleurisy " (presumably unilateral) in 10 per cent of 126 cases. These figures were based on clinical diagnosis or paracentesis, whereas ours were based mainly on radiological diagnosis which allows the inclusion of many small effusions. The frequency of hydrothorax in a series of patients with heart failure will of course increase the longer they are kept under observation, so that actual figures have little significance.

The incidence and distribution of hydrothorax in the different types of heart disease are shown in Table I.

TABLE I

DISTRIBUTION OF HYDROTHORAX IN DIFFERENT TYPES OF HEART DISEASE

Type of Heart Disease	Total Cases of Failure	Hydrothorax			
		Right	Left	Bilateral	Total
Hypertensive ..	136	16	21	8	45
Rheumatic	117	32	11	7	50
Arteriosclerotic ..	57	10	4	3	17
Thyrotoxic	27	7	3	5	15
Syphilitic	16	3	3	2	8
Myxœdematous ..	2	0	0	1	1
Emphysematous ..	1	0	0	0	0
TOTAL	356	68	42	26	136

Hydrothorax (10 oz. or more) occurred in 45 (41·3 per cent) of the 109 necropsies. This agrees closely with the post-mortem figures of Steele (1896), who found hydrothorax in 75 (43.2 per cent) of the 173 cases of failure, and of Cabot (1926) who found it in 79 (43·9 per cent) of 180 cases. The higher incidence of hydrothorax in post-mortem statistics is explained by the fact that they relate to a more advanced stage of heart failure than do clinical statistics.

FIG. 2.—Radiograph showing chronic left hydrothorax depressing diaphragm, from a woman aged 40 with chronic hypertensive heart failure; the left chest was aspirated fourteen times. Necropsy showed no lesion of left lung.

Distribution of Hydrothorax

In our 136 cases, hydrothorax was right-sided in 68, left-sided in 42, and bilateral in 26; included are 11 cases of interlobar hydrothorax, 9 right and 2 left. These figures give the site of hydrothorax when first recognized; an effusion at first unilateral occasionally became bilateral. In the 45 post-mortem cases, hydrothorax was right-sided in 11, left-sided in 9, and bilateral in 25.

The distribution of hydrothorax previously reported is given for comparison in Tables II and III.

TABLE II

DISTRIBUTION OF HYDROTHORAX IN CLINICAL STATISTICS

Author	Cases of Hydrothorax	Right	Left	Bilateral
Steele	27	11	5	11
Stengel	17	5	3	9
Forgeot	25	13	7	5
Lickint	60	23	1	36
Lord	30	16	6	8
Joly	82	40	6	36
TOTAL ..	241	108	28	105
Present Series ..	136	68	42	26

TABLE III

DISTRIBUTION OF HYDROTHORAX IN POST-MORTEM STATISTICS

Author	Cases of Hydrothorax	Right	Left	Bilateral
Steele	75	10	3	62
Cabot	76	14	10	52
TOTAL ..	151	24	13	114
Present Series ..	45	11	9	25

In comparison with previous records, ours show a high incidence of unilateral hydrothorax, and this requires explanation. We believe that pleural transudation often starts on one side of the chest before the other and that hydrothorax is commonly unilateral in its early stage. In response to treatment this process is reversed, and a bilateral hydrothorax disappears first on one side and then on the other. Our figures are based largely on radiological diagnosis in out-patients and therefore apply especially to the early and unilateral stage of hydrothorax. Post-mortem figures, on the other hand, relate to the terminal stages of heart failure and therefore show a relatively high incidence of bilateral hydrothorax.

In the clinical statistics tabulated, the average ratio of right- to left-sided effusions is only 3·8 to 1, and in the pathological statistics 2 to 1, which scarcely justifies the sweeping statements as to the predominance of right-sided hydrothorax found in most text-books. In our series based on radiological and clinical findings the average ratio of right- to left-sided effusions was 1·6 to 1 and in the pathological series 1·2 to 1. If our figures are combined with those quoted, both clinical and pathological, we find that, in 573 cases, hydrothorax was right-sided in 211, left-sided in 92, and bilateral in 270, giving a ratio of right- to left-sided effusion of just over 2 to 1.

Our series contains a far higher proportion of left-sided effusions than has generally been reported, but so do post-mortem statistics. As already stated,

many of the cases included in this analysis were encountered in the course of an investigation of the pulmonary stasis of left heart failure, in which, as we shall show, hydrothorax is usually left-sided. Admittedly this may have influenced our figures, but, even so, we believe that clinical observation has tended to exaggerate the preponderance of right hydrothorax, possibly because dullness due to elevation of the liver has either been mistaken for fluid or has caused a small left hydrothorax to be overlooked.

Distribution of Hydrothorax in Different Kinds of Heart Disease

It will be observed from Table I that in hypertensive heart failure left hydrothorax is appreciably more frequent than right, while in rheumatic heart disease right hydrothorax is thrice as frequent as left. The rheumatic group, consisting mainly of mitral stenosis, represents a predominantly right heart failure and hypertension a predominantly left heart failure. Before considering the significance of this relationship, we may note the influence of the heart rhythm (see Table IV).

TABLE IV

DISTRIBUTION OF HYDROTHORAX IN RELATION TO HEART RHYTHM

Rhythm	Hydrothorax			
	Right	Left	Bilateral	Total
Normal rhythm	25	30	16	71
Auricular fibrillation ..	43	12	10	65

In failure with normal rhythm left hydrothorax is rather more frequent than right, but in failure with fibrillation right hydrothorax is almost four times as frequent as left. The influence of rhythm is partly explained by the fact that normal rhythm is common in hypertensive failure and fibrillation in rheumatic failure, but not entirely, since the effect of rhythm still holds in certain ætiological groups (Table V).

TABLE V

DISTRIBUTION OF HYDROTHORAX IN NORMAL RHYTHM AND FIBRILLATION

Heart Lesion	Rhythm	Hydrothorax	
		Right	Left
Hypertension ..	Normal	10	19
	Fibrillation	6	2
Rheumatic disease	Normal	7	5
	Fibrillation	26	6
Aortic disease ..	Normal	5	8
	Fibrillation	7	2

Thus in hypertension and aortic disease, left hydrothorax predominates with normal rhythm and right hydrothorax with fibrillation. Similarly, in the rheumatic group, the incidence of left hydrothorax is higher in cases with normal rhythm than in those with fibrillation. The significance of this is discussed later.

Hydrothorax in Left Heart Failure

Hydrothorax in the absence of œdema has long been recognized, but that it may be part of the pulmonary congestion of left ventricular failure is not yet generally appreciated. In a previous publication (Bedford, 1939) it has been shown that hydrothorax may follow attacks of pulmonary œdema and that it may occur in hypertension, coronary occlusion, and syphilitic heart disease in the absence of or before signs of systemic congestion.

Our present series includes 24 cases of left heart failure with hydrothorax: in 9 the congestion remained confined to the lungs, and in the remainder hydrothorax preceded appreciable signs of systemic congestion. The hydrothorax was left-sided in 20 cases, right-sided in 2, and bilateral in 2. In a series of 154 cases of left ventricular failure Bedford observed hydrothorax in 38: it was left-sided in 18, right-sided in 9, and bilateral in 11; three cases had interlobar effusions. Normal rhythm was present in all cases. Thus hydrothorax in left heart failure has a definite predilection for the left side of the chest (see Figs. 1, 2, 3, & 5). The following cases are briefly quoted as examples of left heart failure with hydrothorax and pulmonary œdema.

Case 1. *Hypertension, coronary occlusion, paroxysmal dyspnœa, left hydrothorax*

Male, aged 64, first seen 23.5.35.

History. Coronary thrombosis three years previously, since which he had been liable to anginal pain on effort. Severe anginal pain at rest five weeks ago, followed by nocturnal dyspnœa and pulmonary œdema.

Examination. Pulse 90, regular. Arteries thickened. Blood pressure 195/115 mm. Apex-beat displaced to left, systolic murmur at apex. No œdema, cervical veins not engorged, liver not enlarged. Râles at both lung bases and dullness at left base. X-ray: pulmonary congestion and left hydrothorax. Cardiogram: inversion of T_2 and T_3. Treated by digitalis and salyrgan, and by aspiration of left chest. He recovered and went abroad, but died in November 1936.

Case 2. *Hypertension, paroxysmal dyspnœa, bilateral hydrothorax*

Male, aged 39, first seen 23.8.35.

History. Hypertension recognized for several years. For 9 months subject to paroxysms of nocturnal dyspnœa, recently severe, with blood-stained expectoration.

Examination. Regular pulse. Arteries thickened. Blood pressure 205/160 mm., marked alternation. Slight enlargement of heart to left; gallop rhythm at apex. Cervical veins not distended; no œdema; liver edge just palpable. Râles over both lungs and dullness at left base. X-ray: a large left and a smaller right hydrothorax. Cardiogram: left axis deviation, QRS splintered, T_1 negative. Treated by digitalis and salyrgan, and aspiration of left chest. Lungs became dry and hydrothorax cleared completely; he returned to work for six months, after which pulmonary congestion recurred, and he died in March 1936.

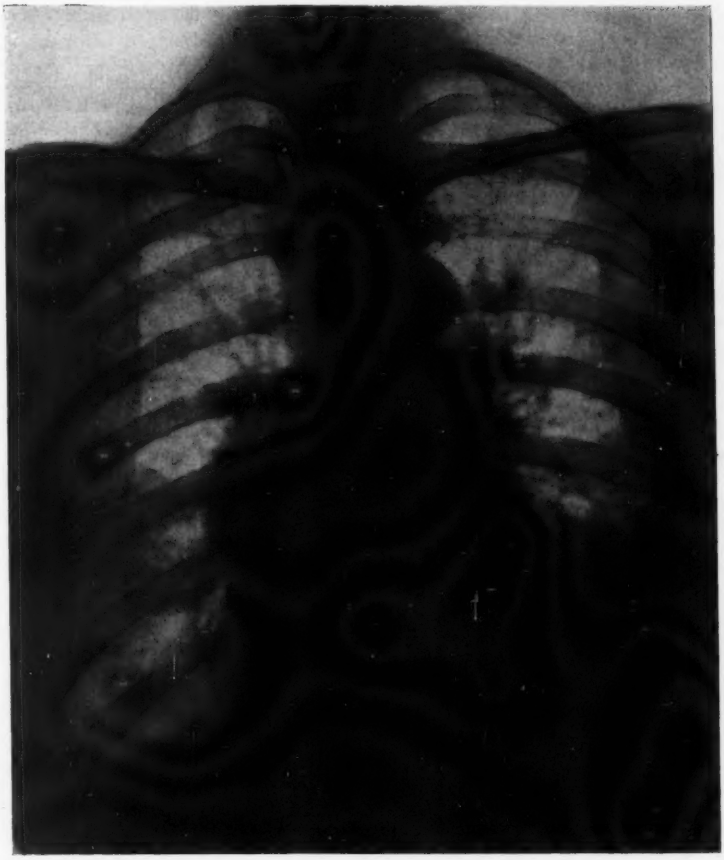


FIG. 3.—Radiograph showing left hydrothorax in a man aged 44, with hypertension and paroxysmal dyspnœa.

Case 3. *Hypertension, paroxysmal dyspnœa, left hydrothorax*

Male, aged 53, first seen 3.5.37.

History. Paroxysmal dyspnœa and nocturnal cough for 4 months, treated as bronchitis.

Examination. Pulse 128, regular. Arteries thickened. Blood pressure 170/110 mm. Slight pulsus alternans. Gallop rhythm at apex. No œdema; cervical veins not distended; liver palpable. Râles at both lung bases and dullness at left base. X-ray: pulmonary congestion and left hydrothorax; moderate cardiac enlargement. Cardiogram: normal rhythm, QRS splintered and T_1 negative. W.R. negative. Venous pressure, 10 cm. Arm to tongue circulation time (decholin), 28 secs. Treated with digitalis and salyrgan, the hydrothorax cleared up while in hospital.

Case 4. *Aortic incompetence, probably syphilitic, paroxysmal dyspnœa, hydrothorax*

Male, aged 60, admitted to hospital 22.7.38.

History. No rheumatic fever or chorea. For 7 months subject to attacks of

nocturnal dyspnœa with cough, wheezing, and frothy expectoration. Occasional sternal pain unrelated to effort.

Examination. Pulse regular, collapsing. Blood pressure 140/50 mm. Heart enlarged to left; aortic diastolic murmur. No œdema, no distension of cervical veins, liver not enlarged. Dullness and râles at left lung base. X-ray : dilated ascending aorta, right interlobar and left basal hydrothorax. Cardiogram : left axis deviation, QRS splintered, T_1 and T_2 negative. W.R. negative. He improved with treatment and left hospital, but died suddenly in December 1938.

Obliterative Pleurisy in Relation to Hydrothorax

In the 109 necropsies of heart failure that were analysed and in the 23 necropsies on our own cases, making 132 in all, complete obliteration of one or both pleural cavities occurred nine times; in seven the left pleural sac was obliterated, in one the right, and in one both sides. In five cases there was a contralateral hydrothorax, in the others none. Thus, obliterative pleurisy does occasionally explain a unilateral hydrothorax, though rarely in our cases a left-sided one. Pleural adhesions of some degree were of course common, and often involved the same side as the effusion. Where hydrothorax was recent there was usually little pleural change, but where it was chronic the pleura was sometimes much thickened, and in several cases there was atelectatic bronchiectasis of the lung on the affected side.

Pulmonary Infarction in Relation to Hydrothorax

In our 356 cases of heart failure, pulmonary infarction was recognized at some period in 46: 33 of these also had hydrothorax, but in only 13 of these could the hydrothorax be regarded as the sequel of infarction; 8 were right-sided and 5 left-sided effusions. In the remainder these two conditions seemed to be unrelated, either because hydrothorax preceded the infarct, or because the two occurred at different periods; in three cases the infarct and the hydrothorax were on the opposite sides.

Thus, as far as clinical observation goes, hydrothorax could only be attributed to infarction in 13 of 136 cases. Necropsies were obtained in 23 cases, in 9 of which there were lung infarcts, 5 on the right side, 3 on the left, and 1 bilateral. Hydrothorax was present in 8 of these 9 cases; in 4 it was bilateral, and in 4 unilateral and on the same side as the infarct. In the 109 post-mortem records analysed, lung infarcts were recorded in 42 cases, of which 20 also had hydrothorax.

It is difficult to draw any precise conclusions as to the rôle of pulmonary infarction in the causation of hydrothorax. In the terminal stages of heart failure, they are frequently associated, but even so a causal relationship must not be assumed too readily, for hydrothorax may precede the infarct or may be bilateral when the infarct is unilateral. Furthermore, in the absence of heart failure, for example after surgical operations, infarction does not usually cause an appreciable pleural effusion. If, as we believe, hydrothorax is a sequel of pulmonary venous engorgement, then the presence of an infarct in addition is

not of much consequence, apart from causing some degree of inflammatory reaction in the pleural transudate.

The average hydrothorax recognized clinically is by no means a terminal event, for in half of our cases it cleared up completely within a few weeks or months in response to treatment, rarely leaving any residual signs, and there is no reason to believe that pulmonary infarction was at all common. Chronic hydrothorax, on the other hand, does appear often to be associated with an infarct.

Interlobar Hydrothorax

There were 11 cases of interlobar hydrothorax in this series, 9 right- and 2 left-sided. An anterior radiograph shows a sharply defined lemon-shaped shadow in the right lung field (Fig. 4), or a more diffuse mid-zone opacity. An oblique or lateral view may demonstrate the effusion better. At least 29 cases of interlobar hydrothorax have previously been reported (Stewart, 1928; Kiser,

FIG. 4.—Radiograph showing pulmonary congestion and right interlobar hydrothorax, from a man aged 67, shortly after coronary occlusion; no œdema or systemic congestion.

1929; Freedman, 1931; Steele, 1931; Austrian, 1932; Vessel, 1932; Stein and Schwedel, 1934; Shiflett, 1935), apparently all right-sided and usually situated between the upper and middle lobes.

The occurrence of interlobar hydrothorax is usually attributed to obliteration of the main pleural cavity by adhesions, and post-mortem confirmation of this has been recorded (Stewart, 1928). Such an explanation is not always applicable, as in five of our cases there was also an effusion in the main pleural cavity (Fig. 5). Stein and Schwedel suggest that there are two types of inter-

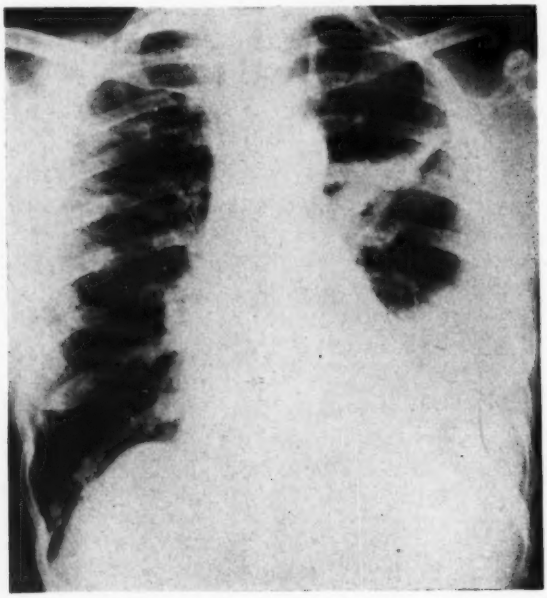


FIG. 5.—Radiograph showing left basal and small left interlobar hydrothorax, from a woman aged 47, with syphilitic aortitis and heart failure.

lobar hydrothorax, one a true encysted effusion, the other an indentation of the lung fissure, into which fluid seeps from the main pleural cavity; but this latter explanation seems to us unlikely. Zdansky (1929) points out that œdema and congestion of the lung in heart failure may be unevenly distributed and may be localized at the site of pleural thickening or pulmonary fibrosis. Radiographs often show an œdematous or thickened interlobar septum in heart failure, or even a thin lamellar effusion (Fig. 6), which represents the early stage of interlobar hydrothorax. The lung fissure has no connection with the systemic (azygos) venous system, and transudation at this site can only be explained in terms of pulmonary engorgement, a point of some significance in relation to the pathogenesis of hydrothorax.

FIG. 6.—Radiograph showing pulmonary congestion and lamellar interlobar hydrothorax; right basal hydrothorax recently aspirated. From a man aged 62, with coronary occlusion, who was free from œdema and systemic congestion.

Analysis of Pleural Fluid

Fifty samples of pleural fluid from 27 cases were investigated in respect of specific gravity, cytology, and protein content. The specific gravity, determined by dropping the fluid into xylol chloroform mixtures of known specific gravity, varied between 1005 and 1034, the average being 1011·5; even in the same patient it varied by as much as 3 or 4 points at different times.

The cell content of the centrifuged deposit varied considerably in different specimens examined. Red cells were usually plentiful. Most obvious were endothelial cells, usually discrete, but quite often in plaques of 3 to 8 cells, and constituting up to 80 per cent of all cells in some samples. Lymphocytes were always present and sometimes predominated, ranging from 5 to 70 per cent. Polymorphs were usually scanty, but occasionally accounted for 70 per cent of all cells. The average cell content in 31 specimens was: lymphocytes 45 per cent, endothelial cells 38 per cent, and polymorphs 17 per cent. A few specimens which showed a high polymorph count were from cases of pulmonary

infarction; more often polymorphs were absent or did not exceed 10 per cent. The usual cell formula corresponded to the " mixed type " of effusion, i.e. partly transudate, partly exudate.

The total protein ranged between 0·6 and 4·2 per cent, averaging 2·1 per cent; albumin 1·3 per cent, and globulin 0·7 per cent. Although the specific gravity and protein content of hydrothorax are usually lower than in a typical inflammatory effusion, there is considerable overlapping, and it seems doubtful if any sharp differentiation between transudate and exudate can often be made from analysis of the fluid alone. A high polymorph count and a frankly blood-stained fluid certainly suggest an infarct. Considering that pleural transudate is in contact with a chronically congested lung, it is not surprising to find that it often shows some degree of inflammatory reaction.

Clinical Course of Hydrothorax

Barié (1902) regarded true hydrothorax as a terminal event in heart failure, a view that was probably correct at the time. The advent of mercurial diuretics has contributed much towards a better outlook in these patients, and now they often survive the first appearance of hydrothorax by years. Salyrgan and similar preparations are of great value in dehydrating the lungs and pleuræ, and their use has largely obviated the need for aspiration.

In 70 of our patients the hydrothorax cleared up completely under observation, in half of them within a month and in all but 8 within nine months. In 21 cases the hydrothorax became chronic, persisting after other signs of failure had disappeared, and in 13 cases it was observed to persist for over a year (see Fig. 2), and once for 4 years. These patients were kept more or less free from œdema by digitalization and regular injections of salyrgan. In only 38 cases was hydrothorax a purely terminal event, appearing within a few months of death.

When hydrothorax cleared up within a few months, it left no residue, and X-rays showed normal clarity of the lung base and free diaphragmatic movements. In the more chronic forms, especially when associated with pulmonary infarction, there was usually evidence of pleural thickening and adhesions.

Pathogenesis

A raised venous pressure is accepted as an essential factor in the complex process of transudation of fluid into the tissues in heart failure. The pleural sacs have both a systemic and a pulmonary venous drainage. The parietal pleural veins are systemic and drain into the superior vena cava or its tributaries—mainly by the azygos veins, which are also connected with tributaries of the inferior vena cava via the lumbar veins. The capillary network of the visceral pleura, though its arterial supply is sometimes derived from the bronchial vessels, drains almost entirely into the pulmonary veins (Miller, 1937). Hydrothorax must therefore be considered in relation both to systemic and to pulmonary venous engorgement.

It has generally been assumed that hydrothorax is a manifestation of systemic venous stasis, and therefore *ipso facto* a transudate from the parietal pleura; yet there is scanty evidence to support such a view. West's case (West, 1909) of unilateral hydrothorax associated with azygos venous thrombosis, in a patient with nephritis, is usually cited, and the old azygos theory of Bacelli (1867) has so often been quoted in explanation of the supposed predominance of right-sided effusions that we have perhaps grown accustomed to thinking of hydrothorax in terms of the azygos veins. The factor of pulmonary venous stasis has certainly received inadequate consideration.

Bacelli postulated a constriction of the vena azygos major which was supposed to be stretched over the right lung root by downward traction of the dilated right heart. In fact, the diaphragm and heart ascend in heart failure, as shown by radiography, so that Bacelli's explanation must be discarded. Compression of the azygos vein by upward pressure of the dilated right auricle has also been suggested, but Fetterolf and Landis (1909) rejected this view, concluding that direct or indirect compression of the azygos by the heart was anatomically impossible. In view of the free anastamosis between the thoracic veins, compression of the vena azygos major seems to us an inadequate explanation of a right hydrothorax, and provides no explanation of a left hydrothorax. Pressure on the pulmonary veins in the right lung root was considered more likely on anatomical grounds by Fetterolf and Landis (1909) and by Steele (1896).

Fishberg (1937) has discussed the pathogenesis of hydrothorax in relation to left and right heart failure and his views deserve attention. He states that hydrothorax does not occur in isolated failure of the left heart and that pulmonary engorgement by itself cannot produce hydrothorax. He notes that hydrothorax may be absent in pure right heart failure with massive œdema and ascites, and concludes that both systemic and pulmonary stasis are requisite.

All who have investigated hydrothorax have observed that it may occur in the absence of œdema, yet if a raised systemic venous pressure were mainly responsible, as generally assumed, the pleura, with its alternative pulmonary venous drainage, should be the last rather than the first site of transudation. The only satisfactory explanation of hydrothorax without œdema, if we exclude pulmonary infarction, is in terms of pulmonary stasis due to left heart failure, in which, as we have shown, hydrothorax is not infrequent. If hydrothorax were mainly due to systemic stasis we should expect to find it early and constantly in conditions of right heart failure with severe venous engorgement, yet the reverse is the case. In tricuspid disease with failure, ascites is early and hydrothorax late, and the unusual clarity of the lung fields in radiographs has often been remarked (Fig. 7, p. 108). Similarly in heart failure due to atrial septal defect, in which extreme engorgement of the right heart is the rule, pulmonary œdema and hydrothorax are noticeably absent, but ascites is common (Bedford, Papp, and Parkinson, 1941). In mitral stenosis, though failure involves mainly the right heart, there is an obstruction distal to the lungs, so that pulmonary stasis occurs early and hydrothorax is common. To sum up, hydrothorax is found in the same conditions as pulmonary œdema, namely, in left heart failure,

FIG. 7.—Radiograph from case of rheumatic heart disease with longstanding tricuspid incompetence and heart failure with ascites and œdema. There is gross distension of vena cava and enlargement of right auricle, but lung bases are clear.

in combined left and right heart failure, and in mitral stenosis, and it is absent or late in pure right heart failure in which the lungs are spared. From this we may conclude that the essential factor in the production of hydrothorax is pulmonary engorgement, and that as long as the lungs are efficiently drained by the left heart, a rise in systemic venous pressure does not cause pleural transudation.

The occasional occurrence of interlobar hydrothorax supplies the proof that pleural transudation may occur quite independently of systemic congestion, for the interlobar pleura is not connected with the systemic veins. Similarly, when a unilateral effusion is determined by pulmonary infarction and heart failure, the visceral and not the parietal pleura is presumably the source of the fluid, which is probably a transudate with some degree of inflammatory reaction.

Lastly, the pulmonary origin of hydrothorax must appeal to all familiar with the radiology of heart failure. When a film of the chest, especially in a patient free from ascites and œdema, shows opacity around the lung roots, an œdematous right interlobar fissure, and basal pleural fluid (Fig. 6), the inference that these are alike manifestations of pulmonary congestion is difficult to avoid. Indeed, Zdansky (1929), in his classical account of the radiology of lung stasis, gives hydrothorax as the final stage.

We can now consider unilateral hydrothorax in terms of pulmonary as opposed to systemic congestion. We refer to those cases seen in the early and unilateral stage of pleural transudation, and not to the minority in which the site is determined by local conditions such as lung infarct or contralateral pleural obliteration.

We have shown that there is a definite relation between the site of the hydrothorax and the underlying heart condition, a conclusion previously reached by Steele. Pure left-sided heart failure, hypertension, and normal rhythm favour a left-sided hydrothorax, whereas failure with auricular fibrillation favours a right-sided one. Established auricular fibrillation is almost incompatible with pure left heart failure (Bedford, 1939), for it always involves systemic as well as pulmonary congestion, and is associated with some degree of right auricular dilatation. Thus it appears that enlargement of the left heart without right auricular dilatation, e.g. pure left heart failure, favours a left hydrothorax, and that dilatation of the right heart favours a right hydrothorax. It is not difficult to believe that enlargement of the left ventricle acts unfavourably on the circulation of the lower lobe of the left lung, either directly by compression, or indirectly by pressure on or displacement of the left pulmonary veins, the lower of which lies directly behind the left ventricle. Similarly, enlargement of the right auricle may affect the right lung root and favour a right-sided hydrothorax.

Anatomical differences between the two lungs have also to be considered, and Dock (1935) has studied their hydrostatic effect in relation to the pulmonary circulation, concluding that, in the usual bodily postures, gravity favours transudation into the right side of the chest. Many other explanations of right hydrothorax have been suggested, only one of which need be mentioned, namely, the effect of a swollen liver which may hinder the movements of the right diaphragm and so impair the circulation in the base of the right lung. Provided that the influence of cardiac enlargement is equally distributed between the two sides of the chest, it seems quite possible that anatomical differences may in some way favour right-sided pleural transudation.

Summary and Conclusions

Old and recent views on hydrothorax have been reviewed and its clinical and radiological diagnosis have been discussed.

Hydrothorax was observed at some stage in 136 (38·5 per cent) of 356 cases of congestive heart failure, diagnosis being mostly radiological, and in 45 (41·3 per cent) of 109 cases of failure examined post mortem. The hydrothorax was right-sided in 68 cases, left-sided in 42, and bilateral in 26; this included

11 interlobar effusions. Neither these nor previous statistics show right unilateral hydrothorax to be as predominant as generally supposed.

A definite relation was found between the site of the hydrothorax and the underlying heart condition. Hypertension, left heart failure, and normal rhythm favoured a left hydrothorax; mitral stenosis, combined right and left heart failure, and auricular fibrillation favoured a right hydrothorax. Clinical hydrothorax, which clears up rapidly with treatment, can rarely be attributed to pulmonary infarction, but in the terminal stages of heart failure and at post-mortem examination infarction is often an associated condition.

Hydrothorax is not uncommon in left heart failure, when it is a complication of pulmonary congestion. This explains its occurrence without œdema. In pure right heart failure ascites without hydrothorax is the rule.

The pleural fluid in hydrothorax may show some degree of inflammatory reaction, probably due to its contact with chronically congested lungs, and no sharp division between transudate and exudate (cardiac pleurisy) can usually be made.

In response to treatment by mercurial diuretics, hydrothorax often clears up completely within a few weeks or months, leaving no residue; but occasionally it becomes chronic and persists for a year or longer.

The pathogenesis of hydrothorax has been discussed and reasons given for regarding it as related to pulmonary rather than systemic venous engorgement, and as a transudate from the visceral rather than the parietal pleura. Unilateral and interlobar hydrothorax can better be explained in terms of pulmonary than of systemic stasis.

We are much indebted to hospital colleagues, especially Dr. G. E. S. Ward, for permission to follow up cases admitted under their care, and to Professor James McIntosh for laboratory facilities and for permission to analyse the post-mortem records of the Bland-Sutton Institute of Pathology. One of us (J. L. L.) has to thank the Medical Research Council for a whole-time grant during a part of this investigation.

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A COMPARISON OF THE MERCURIAL DIURETICS USED IN HEART FAILURE

BY

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Digitalis is without equal in the treatment of heart failure in mitral stenosis with auricular fibrillation, though diuretics may also be needed. But when heart failure occurs with normal rhythm, as in hypertension, mercurial diuretics usually prove more successful than digitalis in increasing the urinary output, in lessening pulmonary congestion, and in relieving dyspnœa. Since the circumstances that demand the use of diuretics are known, it is necessary to learn which preparation is best to prescribe, in what form to give it, and how best to improve upon its own diuretic effect.

The object of this paper is to provide answers to these inquiries, and to continue the investigations carried out in the Cardiac Department of the London Hospital by Thomson (1937). It gives the results of a clinical trial in which selected mercurial preparations were administered in various ways after different methods of premedication.

The Investigation Described

Fifty patients with heart failure, 30 men and 20 women, were selected for this clinical trial. Hypertension was the cause of the failure in 28, mitral stenosis in 12, and other less common conditions in 10 cases. The need for mercurial diuretics was determined by finding evidence of fluid retention on clinical examination. In some patients with hypertensive heart failure, frank œdema could not be demonstrated, but the symptom of breathlessness and the X-ray appearance of pulmonary congestion gave proof of their suitability for this form of therapy. Each patient was admitted to hospital and confined to bed during the period of investigation. The fluid intake was recorded daily and it was usually restricted to 35 ounces. The daily urinary output was also recorded. For convenience in assessing the results of this investigation, we have referred to the excess of the daily output of urine over the fluid intake, both measured in ounces, as the *diuretic index*. Naturally this figure is less than zero in a patient in whom heart failure is progressing. If vomiting or diarrhœa occurred under observation this received due regard in the interpretation of results. In some of the patients, especially those with mitral stenosis and auricular fibrillation, digitalis had to be given, but its effects had become constant and standard

before a mercurial diuretic was introduced, so that the results remain strictly comparable throughout periods of continued digitalization. The effect of a diminished fluid intake and of rest upon the urinary output was also kept in mind when the diuretic value of any medicine was being decided. The following preparations were submitted for clinical trial: esidrone, mersalyl, neptal, novurit, and salyrgan. Sometimes it was possible to try every preparation after different forms of premedication in the same patient, but more often it was only feasible to compare in a single patient either the preparations or the adjuvants. The preparations were given by intravenous or intramuscular injection in a dose of 2 c.c. by mouth, and by rectal suppository in the case of two preparations. The effects of 307 injections were observed, 197 intravenously and 110 intramuscularly.

Results

An estimate of the diuretic property of drugs, based as it must be on a comparison of the quantity of urine passed following their administration in different patients, requires care in that there may be several variables. We have tried to eliminate these by making allowance for the extent of anasarca at the time each medicine was given; by comparing the diuretic effect of each drug, only when it had been given to the same patient following the same form of premedication; by varying the sequence with which the drugs were given, because the first diuretic response is usually greater than succeeding ones; and by taking into consideration the interval between each administration. The results are presented under three main headings, which deal with choice of preparations, method of administration, and premedication.

I. Choice of Preparation

Judgement of the relative diuretic power of esidrone (prepared by Ciba), mersalyl (B.P. 1936; the variety used in this investigation was prepared by British Drug Houses), neptal (prepared by May and Baker), and salyrgan (prepared by Bayer) was made by comparing the effects of intravenous injection only, following the same form of premedication.

These preparations, which all contain theophyllin as well as mercury, were tried in 15 patients to whom 30 grains (2 g.) of ammonium chloride had been given two hours before each injection. They were not given in the same rotation, so that if esidrone was used first in one patient it was given second in the next patient, and third and fourth in succeeding patients. Again, each preparation that was given first was repeated before the second preparation was tried. That this manœuvre was necessary was shown later when the diuresis produced by the first and second injections were compared in 27 patients: the first injection induced greater diuresis than the second in 22, and the average *diuretic index* for the 27 patients was 72 for the first injection and 49 for the second.

The actual diuresis induced in each of the 15 patients by the four preparations is shown in Table I, and an analysis of these results is given in Table II. From

these data it will be seen that neptal and esidrone proved more efficient than salyrgan and that this were more efficient than mersalyl.

TABLE I

DIURETIC INDEX (EXPRESSING IN OUNCES THE EXCESS OF THE DAILY URINARY OUTPUT OVER THE FLUID INTAKE) PRODUCED BY FOUR MERCURIAL PREPARATIONS GIVEN INTRAVENOUSLY

Case No.	Esidrone		Mersalyl		Neptal		Salyrgan	
	Same Day	Next Day	Same Day	Next Day	Same Day	Next Day	Same Day	Next Day
3	76	0	33	−13	58	−7	24	− 7
5	67	29	58	11	62	5	86	29
6	84	−2	63	4	176	10	92	8
7	67	−17	49	−20	52	− 5	57	3
8	16	44	37	10	45	26	52	5
10	53	18	55	8	83	−1	83	−4
11	34	−8	11	−9	41	−7	27	−4
12	58	35	69	40	26	32	76	50
13	85	5	39	−11	25	−5	24	0
16	43	−5	39	−19	51	−20	13	0
17	26	2	6	0	29	−6	73	−15
21	62	22	65	10	67	12	26	− 7
22	116	10	47	1	84	16	40	−22
23	48	1	49	12	57	5	70	−3
24	96	9	69	−6	64	−19	75	−17
Average diuretic index	62	9	46	1	61	2	54	1

TABLE II

RELATIVE DIURETIC POTENCY OF FOUR MERCURIAL PREPARATIONS. THE NUMERALS INDICATE THE POSITIONS GAINED BY EACH PREPARATION IN 15 PATIENTS

Preparation	Relative Potency			
	1st Place	2nd Place	3rd Place	4th Place
Esidrone	5	3	4	3
Mersalyl	0	3	7	5
Neptal	5	5	3	2
Salyrgan	5	4	1	5

II. METHOD OF ADMINISTRATION

Esidrone, mersalyl, neptal, and salyrgan were tried by intravenous and intramuscular injection. The diuretic effects of mersalyl, neptal, and salyrgan were also compared when given by mouth in tablet form. Novurit was tried as a rectal suppository and sometimes compared with salyrgan suppository. Naturally the diuresis produced by mercurial preparations when taken by mouth was not expected to equal that obtained by injection, so that the value of intramuscular and intravenous injections was compared first; and separately, the relative value of tablets given by mouth and of rectal suppositories.

Intravenous and Intramuscular Injection

The effects of intravenous and intramuscular injections were observed on 15 occasions, always with similar premedication. Each of the four mercurial salts was included in this trial, and esidrone was given both by intravenous and intramuscular injection in 3 patients, mersalyl in 2, neptal in 5, and salyrgan in 5. The results are shown in Table III. The intravenous method induced greater

TABLE III

THE DIURETIC INDEX (EXPRESSING IN OUNCES THE EXCESS OF THE DAILY URINARY OUTPUT OVER THE FLUID INTAKE) OF INTRAVENOUS AND INTRAMUSCULAR INJECTIONS OF FOUR MERCURIAL SALTS.

Case No.	Preparation	Intravenous Injection		Intramuscular Injection	
		Same Day	Next Day	Same Day	Next Day
3	Esidrone	76	0	57	14
4	Salyrgan	73	20	40	12
6	Neptal	176	10	119	1
7	Salyrgan	57	3	48	−8
8	Mersalyl	37	10	24	52
10	Neptal	83	−1	69	2
10	Salyrgan	83	−4	42	−6
12	Neptal	26	32	58	39
12	Salyrgan	76	50	28	38
18	Salyrgan	32	3	62	−11
21	Mersalyl	65	10	56	10
22	Esidrone	116	10	87	21
22	Neptal	84	16	38	−13
23	Neptal	57	5	47	0
24	Esidrone	96	9	62	−13
Average diuretic index		76	11	56	9

diuresis on 13 out of 15 occasions, and this applied to each preparation. In one of two patients where intramuscular injection proved more efficient than intravenous injection this predominant effect was constant during further trials (Fig. 1). The average *diuretic index* was 76 for the first day and 11 for the second day for the intravenous injection and 56 and 9 for the intramuscular injection. The intravenous method was favoured by patients because they experienced greater pain from intramuscular injections.

Oral and Rectal Administration

The diuretic effects of tablets of mersalyl, neptal, and salyrgan, when taken by mouth, were observed during 68 separate trials with the same premedication. All the tablets contained 0·08 g. of the mercurial salt and 0·04 g. of theophyllin. Five different methods of administering them were adopted. Thus, always two hours after 30 grains (2 g.) of ammonium chloride, the dose was 2, 4, 6, or 8 tablets as a single dose, or 2 tablets three times during the day. Six tablets (0·48 g.) and 4 tablets (0·32 g.) produced the best diuretic effect, and this was actually greater than that produced by 8 tablets (0·64 g.). Mersalyl produced

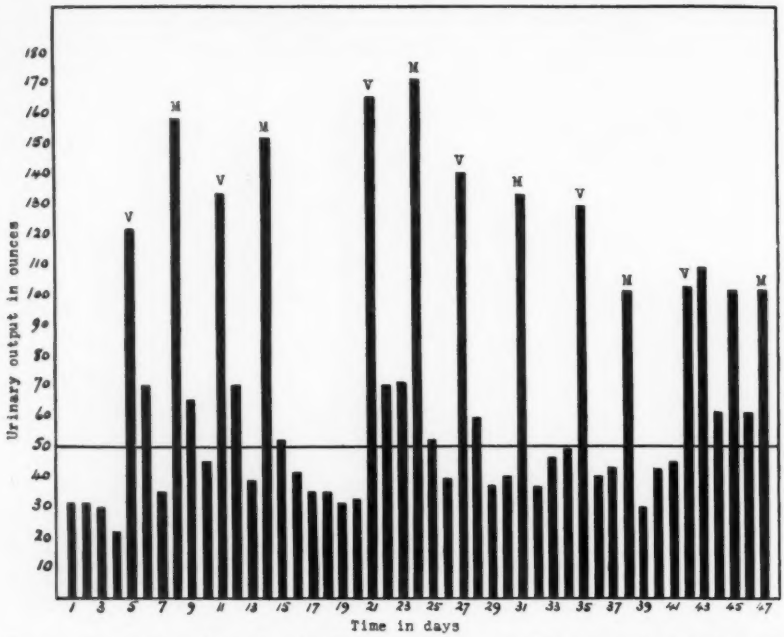

FIG. 1.—Comparison of the diuretic effects of intravenous and intramuscular injections of a mercurial salt in a patient with hypertensive heart failure. The daily fluid intake was kept constant at 50 ounces, and ammonium chloride (15 grains) was given three times daily. V, intravenous injection. M, intramuscular injection.
The superiority of intramuscular over intravenous injection was unusual.

satisfactory diuresis in 12 out of 19 trials and showed an average *diuretic index* of 19. Neptal tablets produced diuretic effects during each of 16 trials and the average *diuretic index* was 32. Salyrgan tablets were successful in 13 out of 23 trials and had a *diuretic index* of 17. Diarrhœa was often occasioned by the tablets when they were taken three times daily but seldom when given as a single dose. Vomiting sometimes resulted from the mechanical effects of swallowing many tablets, for this symptom did not recur when the tablets were repeated. Thus, neptal tablets produced diuresis in a greater measure than mersalyl and salyrgan tablets. As a result of these trials the makers have decided to double the strength of neptal tablets in order to facilitate the correct dose; three tablets now contain 0·48 g. of the mercurial salt and two tablets contain 0·32 g.

Novurit, and sometimes salyrgan, was administered as a rectal suppository in 21 patients. In 8 there was no diuretic response, and the *diuretic index* for all cases was 17. Novurit proved greatly superior to salyrgan suppository (Fig. 2). In 6 cases rectal irritation was produced. Premedication with euphyllin produced no better results than those obtained with ammonium chloride. When the diuretic effects of rectal and oral administration were compared the average *diuretic index* of 17 for the suppository was less than the

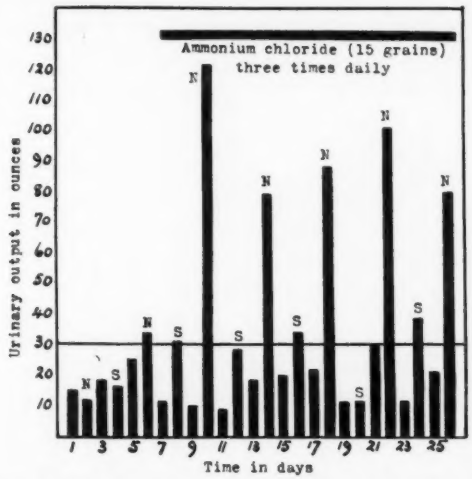

FIG. 2.—Comparing the diuresis produced by novurit and salyrgan suppositories, and showing the increased diuretic response following ammonium chloride in a patient with heart failure in mitral stenosis. The fluid intake was restricted to 30 ounces daily. N, novurit suppository. S, salyrgan suppository.

22 for all tablets, and much less than the 32 for neptal tablets. The discomfort commonly associated with a rectal suppository gave oral administration another advantage. The value of oral administration of mercurial salts in the treatment of hypertensive heart failure is further illustrated in Fig. 3, where it is compared with other methods.

III. PREMEDICATION

The extent to which different methods of premedication amplified the diuresis naturally induced by mercurial salts was another subject of inquiry. Eleven different methods were tried, and in all 507 observations were recorded. When the efficiency of each form of premedication was under test the same mercurial salt was given to each patient, so that when the adjuvant preparation was varied the conditions remained constant. The following preparations and methods were tried: urea (30 g.) two hours before the mercurial salt; euphyllin (0·4 g.) two hours before; digoxin (1 mg.) two hours before; vitamin C given continuously as 2 tablets of redoxon three times daily; and ammonium chloride (15 grains or 1 g.) three times daily for one, two, or three days, or in doses of 15, 45, or 60 grains two hours before. These results were compared with those reached without premedication. Neither digoxin nor vitamin C proved constantly effective in increasing the diuresis produced by a mercurial salt. The other methods were invariably successful and their relative efficiency is shown in Table IV. Ammonium chloride is supplied by Eli Lilly, and by Evans, Lescher, and Webb, in the form of compressed enteric chocolate-coated tablets containing 7·5 grains (0·5 g.). The unpleasant salty taste is thereby avoided and these

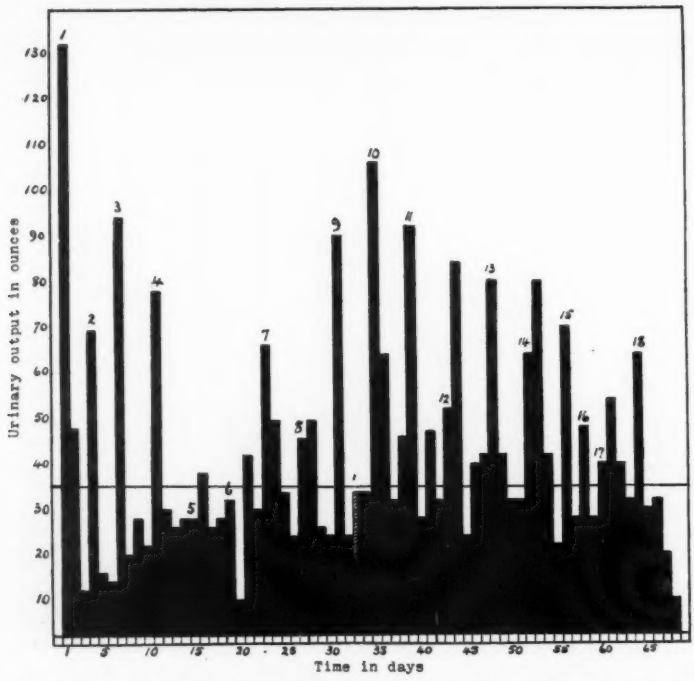

FIG. 3.—The diuresis produced by different mercurial preparations administered in different ways to a patient with hypertensive heart failure during ten weeks in hospital. Ammonium chloride (30 grains) was given two hours before each mercurial diuretic. The daily fluid intake was restricted to 35 ounces.

1. Salyrgan intravenously.
2. Mersalyl intravenously.
3. Neptal intravenously.
4. Esidrone intravenously.
5. Novurit suppository.
6. Novurit suppository.
7. Neptal, six tablets.
8. Salyrgan, six tablets.
9. Neptal, six tablets.
10. Neptal, eight tablets.
11. Neptal intravenously.
12. Neptal, two tablets, three times during one day.
13. Neptal, six tablets.
14. Neptal, two tablets, three times during one day.
15. Salyrgan, four tablets.
16. Mersalyl, four tablets.
17. Mersalyl, six tablets.
18. Neptal, six tablets.

TABLE IV

THE RELATIVE VALUE OF DIFFERENT METHODS OF PREMEDICATION IN AUGMENTING THE NATURAL DIURESIS PRODUCED BY A MERCURIAL PREPARATION

Order of Efficiency	Method of Premedication	Diuretic Index
1	Ammonium chloride (30 grains or 4 tablets) two hours before	69
2	Ammonium chloride (15 grains or 2 tablets) three times a day for three days	61
3	Ammonium chloride (15 grains or 2 tablets) three times a day for two days	58
4	Urea (30 g.) two hours before	57
5	Ammonium chloride (60 grains or 8 tablets) two hours before	54
6	Ammonium chloride (45 grains or 6 tablets) two hours before	53
7	Euphyllin (0·4 g.) two hours before	49
8	Ammonium chloride (15 grains or 2 tablets) three times a day for one day	39
9	Ammonium chloride (15 grains or 2 tablets) two hours before	39
10	No premedication	34

tablets were used whenever ammonium chloride was prescribed. From the table it will be seen that 4 tablets (30 grains or 2 g.) of ammonium chloride, taken by mouth two hours before the administration of a mercurial salt, proved the most efficient method of increasing its natural diuretic property.

Untoward Effects

No serious complications were encountered. Occasionally intramuscular injections, although given slowly, evoked local discomfort or even *pain* which lasted a variable time. *Vomiting* occurred sometimes when a number of tablets had to be taken, but this was not constant and during a second trial it might not recur. *Diarrhœa* usually resulted from the intake of a mercurial preparation by mouth three times daily. *Rectal irritation*, disagreeable, but never severe, affected one-third of the patients using a rectal suppository. *Uræmic symptoms* were seen once in a woman, aged 56, with hypertensive heart failure (Case 38). Slight albuminuria was present when she was admitted to hospital, but there was no evidence of renal failure and the blood urea was normal. Salyrgan was given every third day, alternately by intravenous and intramuscular injection, over a period of 50 days, during which ammonium chloride (15 grains three times daily) had been given continuously. On the fiftieth day the patient was taken ill with weakness, anorexia, vomiting, listlessness, drowsiness, and dryness of the mouth and tongue. Ammonium chloride and salyrgan were discontinued and the fluid intake was increased. Within five days the patient became free from symptoms. Over a period of fourteen days after stopping the drugs the following blood urea values were obtained: 178, 225, 115, 109, 90, and 60 mg. per 100 c.c. After three months, breathlessness returned and there was further need of treatment with mercurial diuretics; these were given following ammonium chloride premedication once a week during the following twelve months with freedom from symptoms of failure and without the advent of uræmic symptoms. As this single experience came to us early in the investigation the blood urea was estimated at least three times in the rest of the series. The first estimate was made before the investigation began, the second during the investigation, and the third towards the end. In none was the blood urea content raised significantly during treatment.

Conclusions

Certain mercurial diuretics were submitted to a clinical trial in 50 patients with heart failure, for the purpose of deciding their relative diuretic potency. The best method of administering them was also investigated, as well as the best means of augmenting their natural diuretic action. Esidrone, mersalyl, neptal, and salyrgan were given in 2 c.c. doses intravenously (197 times) and intramuscularly (110 times). Mersalyl, neptal, and salyrgan were tried orally in tablet form, and novurit and salyrgan were tested as a rectal suppository. Eleven methods of enhancing the diuretic effects of mercurial salts were also tested, and 507 observations were devoted to this problem. The results of this investigation are as follows:

1. Neptal and esidrone when given intravenously or intramuscularly pro-

duced the largest diuresis, rather larger than salyrgan and much larger than mersalyl.

2. The intravenous method almost always induced greater diuresis (average *diuretic index* of 76) than the intramuscular method (average *diuretic index* of 56).

3. Of the two rectal suppositories tried, novurit gave much better results than salyrgan.

4. Neptal tablets by mouth proved more efficient (average *diuretic index* of 32) than mersalyl tablets (average *diuretic index* of 19), salyrgan tablets, or novurit suppositories rectally (each with a *diuretic index* of 17). Ammonium chloride was always given in association.

5. Although the urinary output after oral administration of a mercurial salt was greatest when 0·48 g. (3 new tablets) of neptal were used, satisfactory diuresis was also produced by 0·32 g. (2 new tablets).

6. Thirty grains (2 g.) of ammonium chloride given two hours before the administration of a mercurial preparation proved to be the best form of pre-medication. Enteric chocolate-coated tablets, each containing 7·5 grains (0·5 g.), proved the most convenient form of dispensing ammonium chloride.

7. In a patient confined to bed with heart failure and especially with œdema, standard treatment would include the injection of a mercurial diuretic (2 c.c.) intravenously or intramuscularly every third day, preceded on each occasion by the administration of 4 tablets (30 grains or 2 g.) of ammonium chloride by mouth two hours before. During the ambulatory stage the patient should take neptal tablets (3 in all, or 0·48 g.), twice weekly in the *more severe case* and once a week in the *less severe case*, after the same premedication, and receive an intravenous or intramuscular injection (2 c.c.) at intervals according to need.

We wish to thank Dr. John Parkinson, Physician to the Cardiac Department of the London Hospital, for his helpful criticism of this paper. Dr. P. T. Savage joined in the investigation when he was House Physician to the Department. We acknowledge the able co-operation so loyally given to us by Sisters in charge of the wards. Mr. C. H. Sykes, Ph.C., Chief Pharmacist to the Hospital, has given us great assistance.

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COARCTATION OF THE AORTA WITH PATENT DUCTUS ARTERIOSUS

BY

J. GIBSON GRAHAM AND J. D. OLAV KERR

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While serving in the R.A.M.C. at a military hospital, it has been our good fortune to see a considerable number of patients with congenital heart disease. One of these with coarctation of the aorta presented certain unusual features, notably patency of the ductus arteriosus. In themselves these two defects are not amongst the rarer developmental abnormalities of the cardiovascular system, but their combination in a diagnosis made during life appears to be rare enough to justify detailed consideration.

Evans (1933) stated that coarctation of the aorta was found in approximately one in every 1000 necropsies, while Blackford (1928) estimated the incidence as one in every 1550 necropsies.

Patency of the ductus arteriosus occurred in 262 of Abbott's (1936) series of 1000 cases of congenital cardiac defects; in 40 it was combined with pulmonary atresia or stenosis, in each instance being associated with a septal defect. In the same series of 1000 cases she described 178 examples of coarctation of the aorta, of which 105 belonged to the adult type; 70 were analysed in detail, and in only 6 of these was the ductus arteriosus patent.

Description of the Case

Our patient, aged 25, was the wife of a corporal. There was nothing of note in the family history. Both parents, her sisters, and two brothers were alive and well; her husband was in good health. She herself could remember no previous illness, apart from diphtheria at twelve years, when she was ill for six weeks. As a child she had made no complaint of breathlessness, and took part in all games when at school with enjoyment. Later she was employed as a shop assistant without incident. She was married at nineteen years and was evidently a most active housewife. A year later she became pregnant, and at the seventh month began to suffer for the first time from headache, nausea, and vomiting that was difficult to control. While no œdema was observed, albumin was present in the urine, and on the fifth day of severe symptoms the pregnancy was terminated. It should be noted that there was no history of convulsions. All symptoms disappeared in three days, but she was told she had " kidney trouble " and that another pregnancy would be strongly contra-indicated. This unfavourable prognosis apparently induced

an element of introspection and doubt as to her own well-being which led the patient to present herself at various hospitals for examination; however, little amiss seems to have been found. In September 1940 she was six weeks in hospital with a diagnosis of pyelitis. At this time there was some dysuria which continued to a lesser extent, but at no time had polyuria been noted.

She came under the care of one of us (J. G. G.) some four months later with a provisional diagnosis of chronic nephritis. She made no specific complaint apart from slight discomfort on micturition and lumbar pain when tired. However, she volunteered that she became breathless on exertion and that her lips occasionally turned blue, her nails becoming blue easily in cold weather. She also stated that her feet were always cold, although there was no history of chilblains or of intermittent claudication.

The patient was of small build and stature (height, 4 feet, 11 inches; weight, 91 pounds), and was somewhat pallid and wax-like in complexion. On admission to hospital there was no cyanosis or clubbing of the fingers, nor was there any evidence of dilated vessels in the thorax; there was, however, marked arterial pulsation at the root of the neck. Neither dyspnœa nor orthopnœa was noted. Physical examination of lungs, abdomen, and nervous system did not show any abnormality.

Cardiovascular System. The pulse rate was 70 per minute, the rhythm being regular; the force was good, but the pressure was higher at the left wrist than at the right. The vessels were not hardened to palpation. Pulsation could not be detected either in the abdominal aorta or in the great vessels of the lower limbs. Palpation showed the apex beat to be in the fifth left interspace, four inches from the mid-line. There was marked pulsation of both carotids, and also of the aorta in the episternal notch, but no tracheal tugging. Percussion did not elicit any obvious change in cardiac dulness. On auscultation at the apex three heart sounds were heard, the third following at a short interval after an apparent second sound. One inch internal to the apex beat systolic and diastolic murmurs were present, the heart sounds themselves being well heard and of good tone. At this point the third sound was not audible and the diastolic murmur partly obscured and followed the second sound. There was nothing to suggest the presence of a presystolic murmur. At the aortic cartilage and down the sternum to the xiphoid there was a systolic murmur, but the second sound was pure. Over the aorta and great vessels a systolic bruit was heard, and also in both interscapular areas, especially at the third and fourth left interspaces. In the second left interspace in front, about one and a half inches from the mid-line, a continuous machinery murmur of the water-wheel type was heard, being crescendo during systole and continuing throughout diastole. This murmur was also conducted up to the left clavicle. Throughout the period of observation there were considerable variations in the systolic blood pressure from day to day, but at first there was a constant difference of some 50 millimetres of mercury between the readings obtained in the two arms, the left being the higher. The readings in both upper limbs were greatly in excess of those in the legs, typical figures being: right arm, 175/90; left arm, 225/110; legs, 130 systolic.

On admission the urine showed a trace of albumin and contained a few polymorphs and coliform organisms. No casts were found. A urea concentration test gave a figure of 2·65 per cent at the second hour. The blood urea was 39 mg. per 100 c.c. Later the urine became normal. A gynæcological examination did not reveal any abnormality.

Blood examination: Hæmoglobin 82 per cent, red blood cells 4,700,000 per c.mm., white blood cells 11,200 per c.mm. Examination of blood films, including a differential count, did not reveal any abnormality. The Kahn test was negative. The blood sedimentation rate was well within normal limits.

Ophthalmic examination: The pupils were always moderately dilated and unequal, the degree of inequality varying from day to day; sometimes the one and sometimes the other was the more dilated. The reactions both to light and to convergence were sluggish. The fundi showed no evidence of arterial or venous pulsation or any other abnormality.

Radiological examination of the chest showed enlargement of the right ventricle and a prominent and pulsatile conus; the aortic knuckle was somewhat small (Fig. 1). Fig. 2, a similar view from one of our uncomplicated

FIG. 1.—Antero-posterior view of our patient, at 2 metres, showing right-sided cardiac enlargement, and erosion of ribs.

FIG. 2.—Antero-posterior view, at 2 metres, of an uncomplicated case of patent ductus arteriosus.

cases of patent ductus arteriosus, a female aged 28 years, is included for comparison. Although oblique views of the subject of this paper revealed an apparently normal ascending and transverse aorta, the remainder of the arch could not be visualized. In the left (II) oblique position the aorta and its branches, as Lewis (1931) has described, seemed to rise as a column from the heart shadow up into the root of the neck.

Rösler's sign—erosion of ribs—was present. This is clearly seen in Figs. 1, an antero-posterior view taken at two metres, and in greater detail in Fig. 3. In

FIG. 3.—Left upper quadrant, showing erosion of ribs in detail.

FIG. 4.—Left (II) oblique view of our patient.

Fig. 4, a left (II) oblique view, the prominent pulmonary conus is well seen, but the descending arch of the aorta is not visualized.

An electrocardiogram, Fig. 5, shows changes in the ventricular complexes comparable with those described by Evans and Turnbull (1937), following the work of Wilson *et al.* (1934), as denoting right bundle branch block. This newer curve, which is said to be much commoner than the one standard for right bundle branch block, is characterized by a deep S wave as a component of a wide QRS complex in lead I (measuring 0·12 sec. in this case), and also in lead II, by the QRS complex in lead III being directed downwards ; and by the T wave being upright in leads I and II and inverted in lead III. The changes seen in the sternal lead (Fig. 5) would seem to be in conformity with this diagnosis.

After three weeks' rest in bed the patient stated that she felt fitter in all respects. She had been afebrile throughout this period. The difference between the two radial pulses and the two brachial blood pressures became much less marked. The systolic pressure in the arms, however, remained considerably in excess of that in the legs, typical findings being : right arm, 205/120; left arm, 215/120; legs, 130 systolic.

DISCUSSION

This case presents many unusual features, both in the history and clinical findings. There had been no evidence of cardiac insufficiency until the patient's twentieth year, when she was a seven months primagravida. At that time the

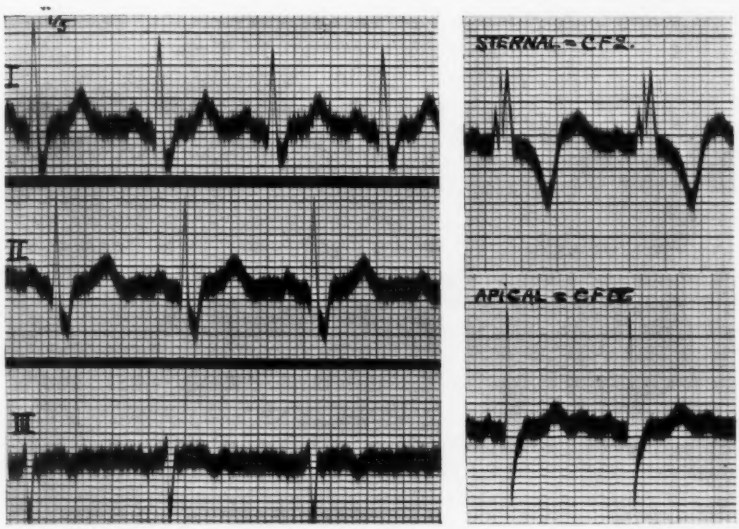

FIG. 5.—Electrocardiogram of the case described, showing a conduction defect comparable with the " newer " type of right bundle branch block.

development of headache, nausea, and vomiting, combined with the presence of albuminuria, were interpreted as being due to renal disease. In view of her subsequent history and the results of the present investigation (which *inter alia* show no evidence of impaired renal function but only of a mild urinary infection that responded to the simplest therapeutic measures) it seems reasonable to suggest an alternative explanation. Her symptoms may be interpreted as due to the development of chronic venous congestion through the late months of pregnancy overtaxing a circulation already hampered by a congenital cardiac defect. It is now suggested that consideration of the physical findings indicates a complex defect of which the several components are outlined.

(1) *Coarctation of the Aorta.* X-ray films taken at two metres showed an ascending aorta of normal size, with a rather undersized knuckle, while the remainder of the arch was not visualized. Moreover, Rösler's sign was present. In addition a loud systolic bruit was heard at the aortic cartilage and was conducted into the neck and to the interscapular area posteriorly. The blood pressure in either arm was markedly raised, and in great excess of that in the lower limbs. The gross difference in pressure between the two upper limbs noted on admission to hospital, presumably with a reduced cardiac reserve, when the left brachial exceeded the right by some 50 millimetres of mercury, is explainable by the coarctation being situated just distal to the entry of the patent ductus to the aorta, from which the great vessels may take an unusual origin.

(2) *Patency of the Ductus Arteriosus*, as instanced by the characteristic machinery murmur heard in the second left space and conducted up to the left clavicle. In this case the shunt was predominantly arterio-venous, the patient being free from cyanosis.

(3) *A Ventricular Septal Defect* is postulated on account of the well-marked and separate systolic and diastolic bruits heard inside the apex beat, and the bizarre cardiogram comparable with the Wilson type, now recognized as indicative of right bundle branch block. Radiological evidence indicated enlargement of the right ventricle and of the conus. In Abbott's analysed series of 110 cases of pulmonary stenosis there was a septal defect in 101. On the other hand, in 70 with aortic coarctation of the so-called adult type there were only 7 instances.

Cowan and Ritchie (1935) point out that patency of the ductus arteriosus may be first recognized during an illness, or in later life on examination for military service or life assurance. We have noted 4 cases of this anomaly in one year in the out-patient department of a military hospital. Similarly, it is of interest to recall that 8 of Lewis's 9 patients with coarctation of the aorta were army pensioners. Evans has recognized six different types of coarctation of the aorta, according to the site of the constriction, the patency of the ductus arteriosus, and the state of the aorta proximal to the constriction. Under this classification our case would be placed in Type I. Among the 8 cases of this type that he described, only one had reached adult life, a man aged thirty years, in whom necropsy showed wide patency of the ductus with enlargement of the right heart. Where the coarctation occurs at its usual site—distal to the origin of the left subclavian—the radial pulses are equal. Various observers, including King (1937), Parker and Dry (1938), and Bayley and Holoubek (1940), have noted that the pulses may be unequal, the right being more forceful than the left, and have explained this by a coarctation at or above the origin of the left subclavian artery. In our case, however, the left pulse was more forceful than the right. In the limited review of the reported cases that we have been able to attempt under present conditions we have only noted two similar cases (King, 1926, and East, 1932). It is realized that the explanation of the physical findings which we have advanced is a purely hypothetical one, and that the final truth can only be revealed at necropsy.

Our grateful thanks are due to Dr. G. A. Allan for his criticism, and to Colonel D. F. Mackenzie, D.S.O., late R.A.M.C., and Colonel R. A. Lennie, T.D., late R.A.M.C., for permission to publish this case.

We have pleasure in acknowledging our indebtedness to Major W. C. Armstrong, R.A.M.C., Major E. G. Recordon, R.A.M.C., and Lieut. D. H. Cummack, R.A.M.C., for the gynæcological, ophthalmic, and radiological examinations, and to Mr. R. P. Danskin, of Edinburgh Royal Infirmary, who took the electrocardiogram.

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A FATAL CASE OF MYOCARDIAL CONTUSION

BY

HUGH BARBER AND G. R. OSBORN

From the Derbyshire Royal Infirmary

Received March 18, 1941

The notes of this case are of interest, because a healthy young man died as the result of an uncomplicated myocardial contusion in the region of the left ventricle. The heart muscle was not ruptured, and there was no blood in the pericardial sac. Death was due to acute pulmonary œdema.

Case History

On February 18, 1941, a sailor 22 years of age was found lying face downwards in the road, with the mark of a large motor-tyre across the left side of his back. It appears that one wheel of a loaded five-ton trailer passed over him. This was about midnight. He was admitted to the Derbyshire Royal Infirmary, where he died about four hours later.

The clinical evidence comes from an experienced house surgeon. The patient was semi-conscious and smelt of alcohol. There were some abrasions on the legs. There were no signs of head or chest injury. The heart and lungs were apparently normal. The problem appeared to be one of concussion, in a man who had taken alcohol. At 1.30 a.m. the pulse rate was 100 and regular; the respirations were 30 to the minute; and there was no obvious distress. At 2.0 there was no change, but by 2.30 the respirations were 40 and at 3.30 the pulse rate 120. About this time he began to bring up large quantities of frothy fluid and he died at 4 a.m.

Post-mortem Examination

The body was that of a strong man of 22 years. He was of average build and 5 feet 8 inches tall.

Externally there were multiple bruises and abrasions over both legs, the right iliac fossa, the nose, and the chin. There was an incomplete fracture of the second left rib in the mid-axillary line, and bruising extended for about an inch all around this, but the pleura was not torn. No other bones were fractured.

The mouth, trachea, and bronchi were filled with blood-stained froth. There were fairly generalized old pleural adhesions on both sides; no hæmothorax was present. The lungs showed general acute œdema, and blood-stained fluid poured from the cut surfaces. No chronic lung disease was

found, and there were no large hæmorrhagic lesions similar to those seen in pulmonary concussion.

The pericardial sac was normal. Pericardial fluid was clear and only slightly increased.

The heart weighed 11 ounces. It was of normal size and shape. There was well-marked bruising of the left ventricle: the distribution of this is shown in the drawings. It was most severe over the whole lateral aspect (margo obtusus) and anteriorly near the apex. On section the bruising was seen to extend from the pericardial surface to a variable depth, this being mostly under half the thickness of the muscle ; in one place only, about the origin of the anterior papillary muscle, did it extend through the muscle and appear beneath the endocardium. The endocardium and valves were undamaged. Bruising was present about the bifurcation of the left coronary artery and followed the circumflex branch for about an inch. The right ventricle was normal, except for very slight bruising near the base. The two auricles and the great vessels were undamaged.

The skull, meninges, and brain were normal.

There was no blood in the peritoneal cavity, though there was bruising of the transverse colon and a small tear of the transverse mesocolon. The other abdominal organs were all normal.

The strong smell of alcohol when he was admitted was due to a bottle breaking in his clothing. The alcohol in the blood was only 85 mg. per 100 c.c.

Microscopically, many small groups of muscle fibres were seen to be ruptured, and this was most marked close to the pericardium. Hæmorrhage had taken place about these small ruptures and beneath the pericardium. The heart muscle otherwise showed a normal structure.

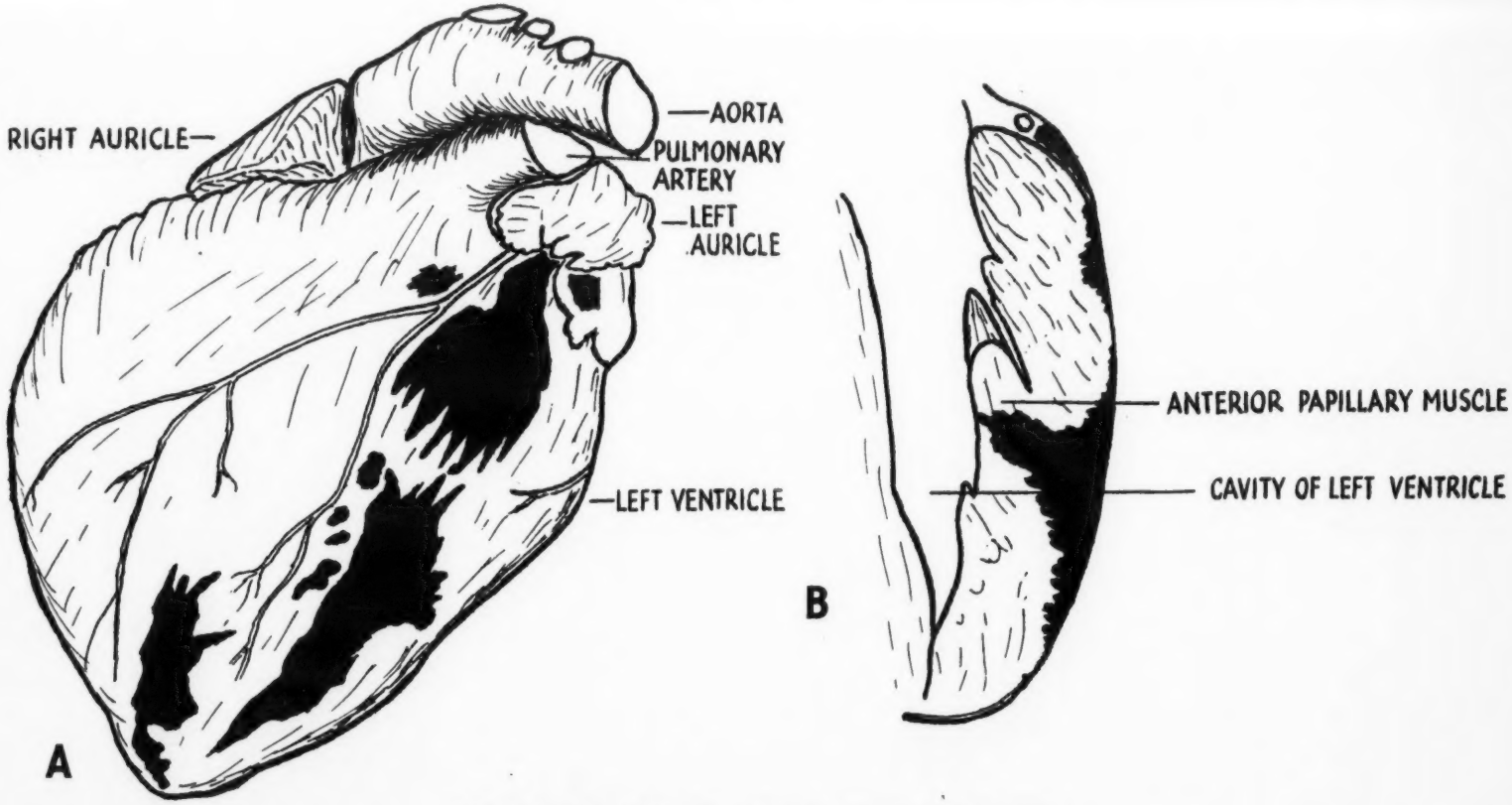
The lungs showed gross congestion of the capillaries and small arteries and veins. Most of the alveoli were filled with serous fluid containing few to many red blood cells. Phagocytic cells laden with hæmosiderin were numerous in the alveolar exudate. The bronchioles and bronchi contained a similar exudate. Free polymorphs were numerous throughout the walls of many of the bronchi, but there was little activity by mucus-secreting cells.

Commentary

(1) *The Type of Accident.*

This was a clear case of compression of the thorax, where the weight on the back pressed him against the ground. There are numerous records of heart injury from such an accident, with and without fractures of the bones of the thorax. It is in the young, with an elastic chest wall, that fractures are less common.

Beck (1940) gives the following list of injuries as causes of non-penetrating wounds or contusions of the heart : falls from a height; impact of a heavy force to the chest; the impact of the steering wheel of a car (this is the commonest accident); the passage of a wheel over the chest; and impact by a fist, a golf ball, or a horse's hoof on the front of the chest. He writes: " Any



Life-size drawings showing the distribution of the bruising of the heart.
(A) Surface of the heart, showing the bruising over the whole lateral aspect and anteriorly near the apex.
(B) Section of the left ventricle showing the depth of the bruising; only in one place did it extend to just beneath the endocardium.

part of the heart can be bruised, any of the chambers ruptured, and any of the valves can be torn." He states that the heart may be ruptured if the body is engulfed and the lower part buried.

(2) *The Site of the Heart Lesion and the Type.*

In this case the lesion was confined to bruising of the wall of the left ventricle; it was sub-pericardial, as shown in the drawing. In the region of the papillary muscle it just reached the endocardium. There was no rupture of the muscle fibres nor injury of the pericardium.

In Warburg's series (1938 and 1940) of non-penetrating wounds of the heart, there were 66 post-mortem records, of which 12 showed rupture of the heart and 6 contusion of the myocardium without rupture. Pericarditis was recorded in a number of cases. Of late results, there were 6 cases of cardiac aneurysm. In a number of the records there was evidence of disease due to natural causes, and in some the evidence of trauma was not convincing. Bright and Beck (1935) analysed 152 cases of rupture of the heart from trauma, in which the left ventricle was ruptured in 37, and each of the other chambers in 30 or more instances. In several instances more than one chamber was ruptured, and in 11 the inter-ventricular septum was torn. They recount 11 instances of failure without rupture, and 12 of recovery. Beck (1940), however, in commenting on these figures and comparing them with animal experiments, in which recovery is the rule, concludes that contusion of the myocardium is a common lesion, and is overlooked frequently.

An interesting study is the question of contusion developing chiefly under the endocardium. Warburg (1938) records such a condition, and also 6 cases of cardiac aneurysm following trauma. In these it would seem reasonable to suppose that the original lesion had been sub-endocardial. Groom (1897), in his case of delayed rupture of the left ventricle, noted that it appeared to have developed from within outwards.

We have one record of a partial rupture of the left ventricular wall extending from the endocardium about half way through the muscle. This lesion also involved the base of the papillary muscle. It was in a young man, who crashed in an aeroplane and had numerous other injuries, including rupture of the right ventricle.

Recently we have obtained a heart with sub-endocardial contusions following " cardiac massage " by a surgeon, when the heart ceased beating under an anæsthetic.

For three years we have made a special study of the heart in all post-mortem examinations after accidents. The variety of injuries met with confirm Beck's observations, that any part of the heart may be ruptured. The site of the lesion need not bear any obvious relation to the situation of the blow.

One justification for publishing this brief note is to emphasize the clinical interest to be found in medico-legal necropsies.

(3) *The Clinical Symptoms.*

The essential features were crushing of the chest; a latent period so far as obvious cardiac symptoms were concerned; and then, three and a half hours

later, circulatory failure in the form of acute pulmonary œdema. This last symptom is of interest in view of the damaged left ventricle, and suggests failure of that part of the heart muscle. We noted similar symptoms (Barber, 1938) in a man who recovered after a blow over the chest. It was concluded that he had sustained a contusion of the left ventricle. A time interval, varying in length, between the injury and any symptoms suggesting heart muscle trauma is usual, and has been a feature of clinical histories from this hospital (Barber, 1940).

Kissane (1937) recorded a series of 15 cases of contusion of the heart: 2 were complicated by a valve rupture, 2 by auricular fibrillation, and in 3 there were fractures. Of the 8 remaining, 4 had symptoms of cardiac distress immediately, and in 4 there was some delay.

Summary

A fatal case of contusion of the myocardium has been described; there was no rupture of the heart muscle. The morbid anatomy has been compared with other records.

Reference is made to clinical histories, already published from this hospital, suggestive of recovery from contusion of the myocardium.

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RUPTURED AORTIC VALVE WITH MYCOTIC ANEURYSM DUE TO ACUTE BACTERIAL ENDOCARDITIS

BY

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From the Cardiographic and Pathological Departments, Harrogate General Hospital

Received March 28, 1941

Although mycotic aneurysms due to bacterial endocarditis are a recognized cause of rupture of one or more cusps of the aortic valve, the following case is of interest owing to the absence of fever.

CASE REPORT

Mrs. R. W., aged 48, was seen on September 16, 1940, with Dr. Bessie Brown. Two weeks previously she had begun to have attacks of shivering. Two days later she was taken ill in a cinema, and on her way home in the black-out collided with a lamp post. This gave rise to pain in the front of the chest on the right side, but there was no bruising. On the following day she was forced to remain in bed on account of retching associated with a dry, irritating cough and with shortness of breath. During the few days prior to examination streaks of blood had been coughed up, and dyspnœa had become increasingly severe; she had lost all desire for food and the tongue had been furred. The illness was afebrile throughout.

Examination revealed a stout, apprehensive woman, looking rather pale. The pulse was intermittent at a rate of about 90. The blood pressure was 150/30 mm. The apex impulse was not palpable, owing to the thick chest wall. The first sound at the apex was clear, but the second sound was followed by a rough diastolic murmur, which could be traced up the left border of the sternum and was audible at the second right space; there was no thrill. Crepitations were present at the bases of both lungs; they extended further up the back on the right side than on the left. The liver was not enlarged. There were no petechiæ; no Osler's nodes; and the spleen was not palpable.

The combination of the rapid onset of left ventricular failure with the murmur of aortic incompetence and a greatly increased pulse pressure suggested a ruptured aortic valve, and she was admitted to hospital on the following day for investigation regarding the possibility of a bacterial endocarditis.

The blood showed a moderate secondary anæmia (hæmoglobin, 70 per cent, red cells, 3·6 millions). The leucocytes numbered 22,900 (polymorphs, 82 per cent). The Wassermann reaction was negative. The urine contained albumen, a few red cells, and a trace of pus. The temperature remained sub-normal throughout, and on this account no blood culture was made.

The electrocardiogram on admission showed a 2:1 A-V block, with an auricular rate of 124 and a QRS of 0·08 sec. (Fig. 1), but six hours later the

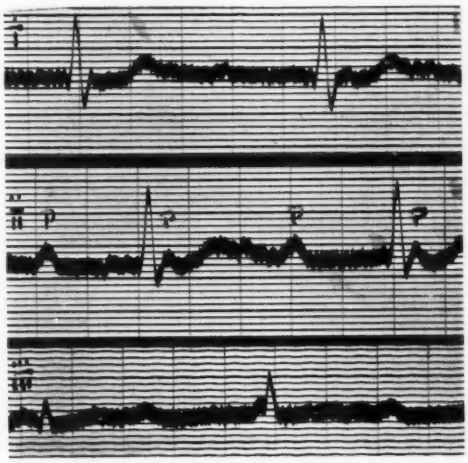

FIG. 1.—17/9/40. 2:1 A-V block (A, 124; V, 62): QRS, 0·08 sec.

auricular rate had risen to 148 and the QRS was 0·12 sec. Digoxin (0·25 mg.) was given four hourly and led to considerable clinical improvement, but the dose was halved after 12 tablets (3 mg.) had been given, since the ventricular complexes

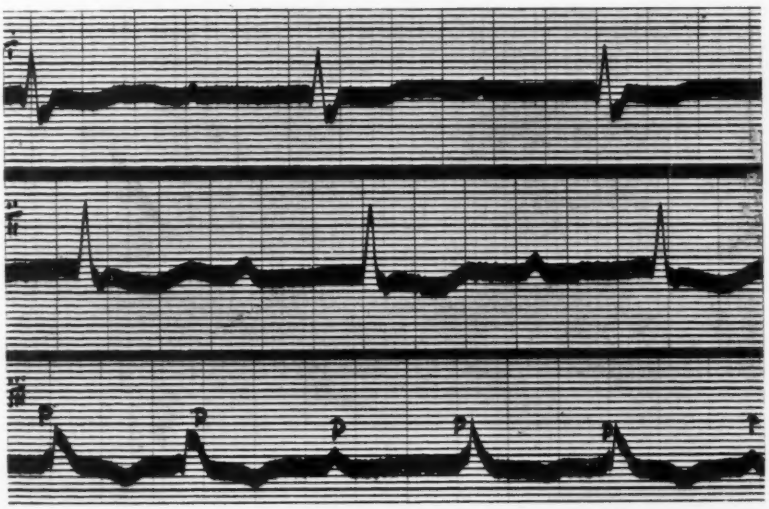

FIG. 2.—19/9/40. 2:1 A-V block in leads I and II (A, 106; V, 53) with right bundle branch block (QRS, 0·12 sec.). There is some depression of the S–T interval. In lead III there is an admixture of 2:1 block and 1:1 rhythm (P–R, 0·56 sec.).

had become those of a type B right bundle branch block with depression of the S–T interval, although the auricular rate had fallen to 106 (Fig. 2). Four days later 1:1 rhythm returned at a rate of 74 and the ventricular complexes were becoming normal. They were quite normal in another four days (Fig. 3.

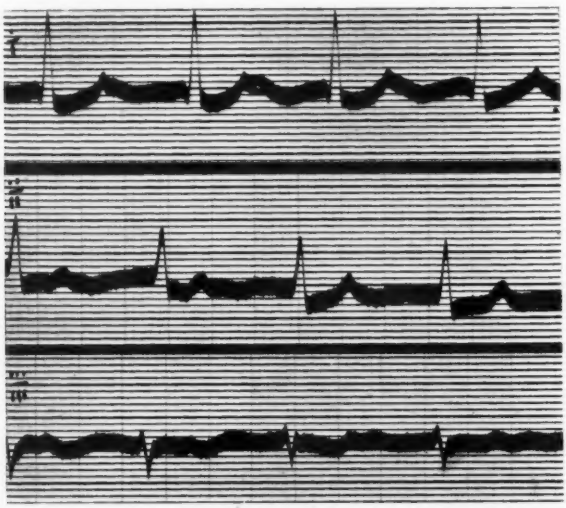

FIG. 3.—26/9/40. 1:1 rhythm at a rate of 74 (P–R, 0·50 sec.). A sinus irregularity gives rise to an apparent variability in the A-V block.

Sept. 26); the P–R interval was 0·50 sec., although a sinus irregularity gave rise to an apparent variability in the A-V block. On September 30, pulmonary œdema set in with further hæmoptysis, and she gradually sank and died on October 2, fifteen days after her admission to hospital. Normal ventricular complexes and 1:1 rhythm were still present a few hours before death.

AUTOPSY

Heart. The heart weighed 425 g., the relative thickness of the right and left ventricular walls being normal. The aortic valve was grossly incompetent, owing to a complete rupture of the right posterior cusp (Fig. 4). Around the site of the rupture, and particularly behind the damaged valve, there was much vegetative proliferation, which on the whole was firmly adherent and extended deeply into the membraneous part of the ventricular septum. There were further wart-like vegetations at the base of the left posterior cusp. The remaining valves were normal. There was no evidence of congenital abnormality.

On opening the right auricle a tumour was seen situated immediately above the junction of the anterior and medial cusps of the tricuspid valve (Fig. 5). The tumour was cone-shaped, with a height and basal diameter of about 1 cm.

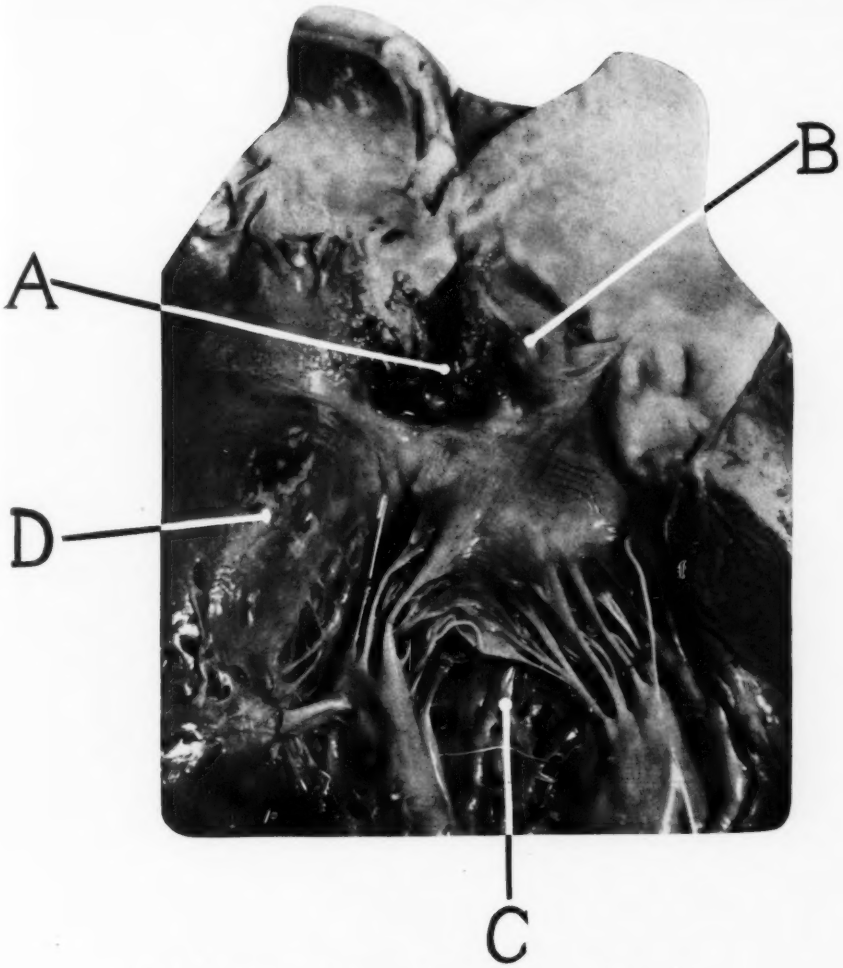

FIG. 4.—Aortic valves showing rupture of the right posterior cusp.
(A) Ruptured aortic valve and excavating cavity.
(B) Left posterior cusp of aortic valve.
(C) Left ventricle.
(D) Septal wall.

It was of the same colour as the auricular wall, was of a firm consistency, and had a smooth surface; it could not be moved on its base. The tumour emerged from the membraneous part of the septum, and on section proved to be an aneurysmal sac that communicated directly with the excavating cavity round the ruptured valve.

Other Systems. There was some œdema and congestion of the lungs,

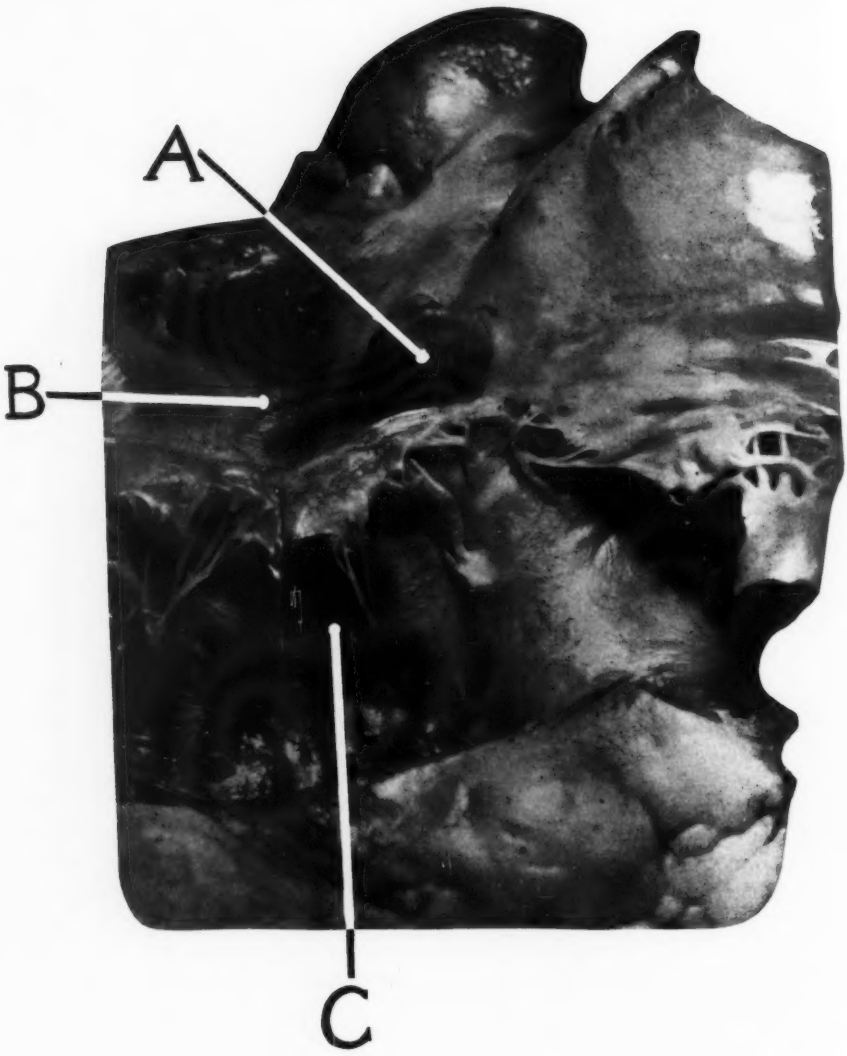

FIG. 5.—Right side of the heart showing the aneurysm.

(A) Aneurysm projecting into right auricle.
(B) Right auricle.
(C) Right ventricle.

especially at the right apex. There was a small right hydronephrosis. The spleen was normal.

Histology

Sections were prepared from the vegetations around the aortic valve and the adjacent myocardium, and also from the centre of the auricular tumour. These were stained with hæmatoxylin, eosin, and Gram's stains.

1. *Aortic Vegetation.* Whilst a little of the tissue consisted of platelet thrombus, the greater part was composed of a loose stroma, which was grossly infiltrated with round cells and polymorphs; numerous red blood cells were also present.

2. *Wall of the Aneurysm.* The aneurysmal wall consisted of three distinct layers. The outer layer was composed of dense fibrous tissue, the middle layer of muscular tissue together with a few fibroblasts and lymphocytes, whilst the inner layer was chiefly platelet thrombus containing a few fibroblasts and polymorphs.

3. *Heart Muscle.* There was no evidence of rheumatic disease.

The diagnosis after autopsy was a ruptured aortic valve with a mycotic aneurysm due to acute bacterial endocarditis.

Discussion

Except for the first two days of malaise the patient was under observation in bed and the temperature never rose above normal. Horder (1908) noted that fever was absent in five out of his one hundred and fifty cases, but he thought it was unlikely that these cases were afebrile throughout, and that they had probably come under observation during an afebrile phase. Perry (1936) had one case in which the temperature was normal for thirteen weeks. Possibly the rapid course of the illness with death from heart failure four weeks after the onset did not allow time for fever to develop.

It is uncertain if digitalis exercises any effect upon intra-ventricular conduction. White (1937) thought that it did to some extent, but Comeau and Hamilton and White (1938) could find no evidence of such an action. The situation of the aneurysm made some interference with conduction inevitable, and complex changes in conduction have been recorded in a similar case by Wishaw (1940). The widening of the QRS began before digitalis was given, during a period of increasing heart failure, and this association has been noted frequently in transient bundle branch block (Comeau, Hamilton, and White, 1938). On the other hand, the right branch block increased while clinical improvement was taking place, and did not regress until four days after the digitalis dosage had been reduced; neither did it recur, although death took place from pulmonary œdema. In the absence, however, of evidence from other sources of a similar action of digitalis it would appear more likely that the transient right branch block was occasioned by the heart failure rather than by digitalis.

SUMMARY

A case of rupture of the aortic valve with a mycotic aneurysm due to bacterial endocarditis has been described. The temperature was sub-normal throughout the illness. Death took place quickly with signs of left ventricular failure.

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MAUDE ABBOTT

Members of the Cardiac Society learned with deep regret of the death of Dr. Maude Abbott, our only woman honorary member, on September 3, 1940.

She was born in Quebec in 1869 and passed her medical life almost entirely in her native country of Canada. Some years were spent in Scotland, where she qualified in 1897; and from 1923 to 1925 she was Professor of Pathology and Bacteriology at the Women's Medical College in Philadelphia. But her medical career was bound up with McGill University, Montreal, where she served as Curator of the Pathological Museum from 1899, as Lecturer in Pathology from 1912 to 1923, and as Assistant Professor of Medical Research from 1925. Her University recognized her faithful service and high achievement by conferring upon her the honorary degree of M.D., and later of LL.D.

In congenital malformations of the heart she found her life interest, and in 1905 Sir William Osler invited her to write on Congenital Cardiac Disease for his *System of Medicine*. From that time patient and methodical research on this subject became her ruling passion, and established Maude Abbott as the greatest authority in the world on congenital heart disease. The main basis of her work was an exhaustive and critical study of pathological specimens wherever these had been reported or were to be found, with the ultimate purpose of clinical classification and recognition. The results are to be found in her contributions to Blumer's *Bedside Diagnosis*, and to Nelson's *Loose-Leaf Medicine*, and notably in the monumental *Atlas of Congenital Cardiac Disease* published by the American Heart Association in 1936. It is an outstanding feature of Maude Abbott's work that, beginning firmly on the pathological footing, she raised from what was merely a disconnected and unproductive series of cases a distinct and defined branch of cardiology—and this with a facility of diagnosis now, of course, rapidly increasing because of the special help afforded by electrocardiography and radiography.

In 1913, the Seventeenth International Congress of Medicine was assembled in London, and Dr. Maude Abbott had the pleasure of attending a meeting of the International Association of Medical Museums, which was founded largely owing to her initiative and of which she became the permanent secretary. Again she found in Osler a powerful friend and supporter; and it was characteristic that she made herself responsible as editor for the classified and annotated bibliography of Sir William Osler's publications, printed in Montreal. From 1907 to 1938 she was editor of the *Journal of Technical Methods and Bulletin of the International Association of Medical Museums*.

Maude Abbott was a woman of simple and unaffected charm, easy to know

and pleasant to meet. The expression of her eyes was eager and searching, yet soft with an engaging kindliness. She travelled a good deal and made friends wherever she went. Unspoiled by success, she was happy and content with the knowledge that she had completed her great and complicated task. She had applied that clean-cut and orderly mind in clearing up the cardiac malformations of the child, and she will be remembered as a pioneer " not content with fragments and scattered pieces of Truth."

JOHN PARKINSON.

KAREL FREDERIK WENCKEBACH

This great Dutch physician, to whose memory a tribute is now paid, was born at The Hague on March 24, 1864. He proceeded from the Gymnasium to the University of Utrecht and in 1888 graduated doctor of medicine with a thesis entitled "*Over den bouw en de ontwikkeling der Bursa-Fabricii.*" While still in Utrecht he began those brilliant researches on extrasystoles, conduction defects, allorrhythmia, and alternation that were published between the years 1898 and 1901. By critical analysis of arterial pulse tracings, before the advent of the polygraph or electrocardiograph, he was the first to show that those disturbances of the human heart represent disorders of properties inherent in the myocardium and are of the same nature as those known to occur in the experimental animal. That great achievement was his alone and, together with Mackenzie's studies of the venous pulse, it initiated a new era in cardiology. The functional activity of the heart in health and disease, its response to drugs, its very structure had now to be studied anew. This in turn paved the way for a wider and better knowledge of other factors than the heart that promote the circulation of the blood and interstitial fluid. Wenckebach was indeed one of the foremost leaders in the renaissance of clinical medicine at the dawn of this century.

Two years after his appointment to the Chair of Medicine in Groningen in 1901, the publication of his first and greatest work "*Die Arhythmie als Ausdruck bestimmter Funktionsstörungen des Herzens*" brought him world-wide fame. In 1911 he passed to the Chair of Medicine in Strasburg and in 1914 to that in Vienna, where a great medical school had been founded, two centuries earlier, by another Dutchman, van Swieten, a pupil of Boerhaave. All Wenckebach's work was characterized by keen clinical acumen, by the utmost precision, and by close correlation of clinical research with that in the laboratory. Graduates were drawn to his clinic from many lands, and notably from the United States. He resigned his chair in 1929.

In addition to his epochal work on cardiac irregularity, of which there is an English translation, he wrote on the radiography of the chest, artificial pneumothorax, beri-beri, circulatory failure, and other subjects. His chief contributions to medical literature between 1898 and 1924 are given in "*Die unregelmassige Herztatigkeit,*" the monumental treatise of which he and Winterberg were the joint authors. A further list is given on page 143. He was a founder and one of the editors of the "Wiener Archiv für innere Medizin." Three terms bear his name: Wenckebach's periods, the slowing of auriculo-ventricular conductivity with periodic dropping of ventricular beats; Wencke-

bach's sign, the paradoxical movements of the chest in chronic mediastino-pericarditis; and Wenckebach's bundle, a band of muscle passing from the superior vena cava to the right auricle.

Wenckebach always felt at home in our country, closely akin to his native land. As a young man he visited Mackenzie in Burnley, and while Gibson's guest in Edinburgh was the central figure of some amusing but apocryphal tales. He opened a discussion on digitalis in London in 1910, and that on heart failure at the Seventeenth International Congress of Medicine in London in 1913. In 1919, when Eastern Europe had been laid waste and destitution and disease were rife, he initiated the Relief Mission to Vienna. In 1928 he was a delegate to the tercentenary celebration in London of the publication of "*De motu cordis*" and was the St. Cyres Lecturer at the National Hospital for Diseases of the Heart. In the following year he delivered an oration at the sesqui-centenary celebration of the Birmingham General Hospital. In 1930 he received the honorary degree of LL.D. from the University of Edinburgh; he made a tour through the Highlands and a pilgrimage to the Research Institute founded by his friend, Sir James Mackenzie, in St. Andrews. Three years later he was again in Edinburgh as the Gibson Memorial Lecturer at the Royal College of Physicians.

Many honours were bestowed upon him. He was awarded the Order of Merit of the Austrian Republic, was a Fellow of the Koninklijke Akademie van Wetenschappen te Amsterdam and of the Kaiserliche Akademie der Wissenschaften, an Honorary Fellow of the Royal College of Physicians of London, the Royal College of Physicians of Edinburgh, the Royal Faculty of Physicians and Surgeons of Glasgow, and the Royal Society of Medicine, an Honorary Member of the Medico-Chirurgical Society of Edinburgh and the Cardiac Society of Great Britain and Ireland, and a Corresponding Foreign Member of la Société Française de Cardiologie.

The charm of the English countryside and the gaiety of Franz Hals' canvases appealed strongly to Wenckebach for he was a lover of beauty in nature and art. He was a warm-hearted man with a keen sense of humour. Among his many friends he counted Gibson, Clifford Allbutt, Osler, Keith, and Cushny. He was a modest man, saying "In medical science there are vast realms of which I have no special knowledge" and, again, "No, I am not a great man; I am a happy man." His particular charm was a radiant joie de vivre and to him the wine and salt of life were given in full measure.

W. T. RITCHIE.

A FURTHER NOTE OF WENCKEBACH'S MEDICAL CONTRIBUTIONS

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